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## THE FRANKLIN INSTITUTE.

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## THE NATIONAL BUREAU OF STANDARDS.


BY SAMUEL. W. STRATTON, Director.


From the beginning of this republic many of the foremost statesmen and scientists have worked assiduously to bring our system of weights and measures to a more satisfactory condition. Washington repeatedly urged upon Congress the necessity for uniform and reliable standards, and in his third annual message to Congress states that "an improvement in the weights and measures of the country is among the important objects submitted to you by the Constitution, and if it can be derived from standards at once invariable and universal may be not less honorable to the public councils than conducive to the public convenience." Thomas Jefferson, then Secretary of State, was directed by Congress to report upon this subject and, after

a most careful consideration, submitted a report in which he outlined two alternative plans, one based upon the retention of the then existing standards, fixing them, however, by some invariable standard, and the other a decimal system based upon the length of a pendulum beating seconds. President Madison, in 1817, reminded Congress that nothing had been accomplished in reforming and unifying the system, whereupon the whole subject was referred to John Quincy Adams, then Secretary of State. Mr. Adams gave four years of historical research and mathematical study, and prepared a report which has become a classic in metrology, but which advised delay until the time when nations had agreed on a universal standard, or until the subject of a universal standard had received more attention.

Notwithstanding these efforts and the reports of various individuals and committees, Congress has never exercised the power delegated to it by the Constitution, with the exception of an Act of May 19, 1828, relative to the adoption of a troy pound as a standard to be used in the coinage of money, the language of which is as follows: "For the purpose of securing a due conformity in weight of coins in the United States to the provisions of this title the brass pound weight procured by the Minister of the United States at London, in the year eighteen hundred and twenty-seven, for the use of the Mint, and now in the custody of the Mint at Philadelphia, shall be the standard Troy pound of the Mint of the United States, conformably to which the coinage of the United States shall be regulated."

Previous to this, by an act passed in 1799, Fifth Congress, second session, it was ordered that "The Surveyor (of each port of the United States) shall, from time to time, and particularly on the first Monday in January and July each year, examine and try the weights, measures and other instruments used in ascertaining the duties of imports, with standards to be provided by each collector at the public expense for that purpose, and when disagreements or errors are discovered, he shall report the same to the collector, and obey and execute such directions as he may receive for the correction thereof, agreeably to the standards aforesaid.

Apparently this act was not enforced, probably for the reason that no standards had been adopted by Congress or by the Treasury Department. On May 29, 1830, the Senate passed a resolution directing the Secretary of the Treasury to have an examination made of the weights and measures in use at the principal custom-houses. The duty of making the examination was intrusted to Mr. F. R. Hassler, Superintendent of the United States Coast and Geodetic Survey, who was at that time the only man of recognized scientific attainments in the employment of the Treasury Department. Mr. Hassler, under date of January 27, 1832, reported that he had found large discrepancies among the weights and measures in use. He was thereupon directed by the Secretary of the Treasury to secure apparatus and establish a shop wherein copies of certain standards adopted by the Treasury Department could be made for distribution to the various custom-houses. The avoirdupois pound adopted was derived from the troy pound of the mint, and the distance between certain lines on a metal bar in the possession of the Department, and supposed to conform with the English yard, was taken as the standard of length.

In June, 1838, Congress passed the following resolution:

"*Resolved*, That the Secretary of the Treasury be, and he hereby is, directed to cause to be made a complete set of all the weights and measures adopted as standards, and now either made or in progress of manufacture for the use of the several custom-houses, or such persons as he may appoint, and for the use of the States respectively, to the end that a uniform standard of weights and measures be established throughout the Union."

On July 27, 1866, the following joint resolution was adopted: Be it

"*Resolved*, by the Senate and House of Representatives of the United States of America in Congress assembled, that the Secretary of the Treasury be, and he is hereby, authorized and directed to furnish to each State, or to be delivered to the Governor thereof, one set of standard weights and measures of the metric system for the use of the States respectively." Here, again, the selection of the

standards necessary to carry out the foregoing resolutions was left to the Secretary of the Treasury, who procured from abroad copies of the original metric standards.

Since that time Congress has provided for the construction and verification of the standard weights and measures for the custom-houses of the United States and for the several States. The custody of the standards adopted by the Treasury and the carrying out of the provisions made by Congress remained until July 1, 1901, under the direction of the Superintendent of the Coast and Geodetic Survey, who served also in the capacity of Superintendent of the Office of Standard Weights and Measures.

In 1866 the metric system, while not adopted by Congress, was made lawful throughout the United States, but the standards of this system were not yet satisfactory, and in 1875, more than half a century after Adams had recommended a conference between nations for the purpose of establishing world-wide uniformity in standards, such a conference was held, and, as a result, there was established in Paris a permanent international bureau of weights and measures. In the negotiations leading up to the establishment of this bureau, Prof. Joseph Henry and Mr. J. E. Hilgard represented the United States. Many of the great scientists of the world were engaged for several years in perfecting prototypes of metric standards, and in 1899 these were ready for distribution among the seventeen nations represented in the International Conference. So important were considered the details of bringing the standard meter and kilogram to the United States that the Department sent special commissioners to Paris for them. Mr. George Davidson, then assistant in the United States Coast and Geodetic Survey, and Mr. O. H. Tittman, now superintendent of that department, accompanied these valuable standards from Paris to Washington, where they were opened in the presence of the President, the Secretary of State, and a distinguished company of scholars invited to the White House on that occasion. These standards were then placed in the custody of the office of Standard Weights and Measures. They are now used as the basis of all comparisons of

mass and length in this country,even in the common systems. There is at the present time no satisfactory standard yard in the possession of the Government. The early standards procured by the Secretary of the Treasury are so poorly constructed, and the lines so broad that a more accurate yard may be made by means of the standard meter. Troy and avoirdupois pounds submitted for inspection are tested with metric weights or with standards which have been derived from the standard kilogram. That is to say, the standard meter and kilogram are so well constructed that more accurate standards in our common systems may be produced in this manner than by comparison with any standard pounds or yards in existence.

It has been seen that, until very recently, the provisions made by Congress covered only the common measures of weight, length, and capacity. The facilities of the office of Standard Weights and Measures were exceedingly limited, and the exercise of its functions confined to departments of the general government and the States. The set of standards furnished each State consisted originally of the most ordinary standards of length, weight and capacity. Later, a few metric standards were added to these, but in few instances have these States provided facilities for the proper comparison and use of these standards by the general public. In some States the standards have been destroyed or lost track of, and we find little legislation pertaining to weights and measures other than to fix the number of pounds to the bushel, to be used in measuring grain and other products. An investigation carried on last summer by a government official disclosed a condition of affairs in regard to the common weights and measures of the country that would hardly bear publication. I am told that in your own city of Philadelphia there is no official whose duty it is to inspect the weights and measures in common use. This statement, however, has not been verified, and I sincerely hope it is not true. The duties of State and city dealers should include the testing of water and gas meters, and perhaps, eventually, electric meters; but certainly all of these standards and measuring instruments are in

common use by the people. And it is the duty of the general government to provide such officers with suitable standards, measuring instruments, and instructions governing their use. As it is, the general public, scientific institutions and other vast interests are unprovided for, even in the most common cases.

The progress of science and the employment of exact scientific methods by the great industrial and commercial enterprises have brought about conditions which demand a radical change in matters pretaining to standards. Whatever may be said as to the necessity of improvement in the common measures of weight, a length and capacity is *equally* true of the more accurate measurements of these same quantities as applied to scientific investigations in the laboratories of our educational institutions, scientific societies, and manufacturing interests, which demand for the successful completion of their work standards of the very highest order of accuracy. The public interest demands a far greater variety and range of standards than heretofore, such as those used in the measurement of high and low temperatures, pressure, standards of illumination, electrical standards of resistance, current, electromotive force, capacity and self induction, polariscopic, barometric, and many other standards. In many cases the problems involved are far more difficult and complex, and reliable standards difficult to procure. The examination and comparison of standards require the use of the most delicate instruments known to science under the most advantageous conditions as to temperature, freedom from vibration, and laboratory conveniences.

In recent years the demand for accurate scientific standards, and in many cases commercial standards has been met by the standardizing institutions of foreign governments (to which our scientific laboratories and manufacturers have had to repair for them). Frequently the benefits to be derived by the public from fixed and reliable standards are through the medium of a great variety of meters and precise measuring apparatus, such as balances, apparatus for the measurement of lengths, capacity, graduated

glassware, pressure-gauges, thermometers, barometers, metrological apparatus, pyrometers, gas and water meters, voltmeters, ammeters, wattmeters, oil-testers, the instruments used in surveying, navigation and hydrography, apparatus for testing the strength of materials and other properties, and many other instruments; that the graduations and indications of these instruments should agree with the fundamental standards is a question of the most vital importance, and without the facilities for such tests and comparisons the public is deprived of the greatest benefits to be deprived from such standards as may have been recognized by the Government.

The manufacture of physical, astronomical, chemical, and other scientific apparatus has been confined almost exclusively to foreign countries, but this industry is growing in the United States at a rate which will soon place our productions on an equality with those of any other country. Our manufacturers of such apparatus have shown that they can compete with the foreign products in workmanship and design. They have, however, been placed at a great disadvantage, owing to the fact that this Government has not provided them with the necessary standardizing facilities. German and English manufacturers furnish official certificates with their apparatus, and the value of such certificates is so well recognized that we find our own manufacturers quoting prices on their apparatus which has been verified in the institutions of foreign governments.

It was this condition of affairs that led Congress to enact a law March 3, 1901, establishing under the Treasury Department, the National Bureau of Standards, the functions of which include the custody of the official standards, and comparison of all standards used in scientific investigations, engineering, manufactures, commerce, and in educational institutions, with the standards adopted or recognized by the Government, the construction when necessary of standards, their multiples, and submultiples, the testing of standard measuring apparatus, and the solution of problems which arise in connection with standards. It is also authorized to make physical and chemical researches

for the purpose of determining physical constants, and the properties of materials when such data are of great importance to scientific or manufacturing interests. The Bureau is authorized to exercise its functions for the departments of the Government, for any State or municipality within the United States, scientific society, educational institution, firm, corporation, or individual engaged in manufacturing or other pursuits requiring the use of standards, or standard measuring instruments.

A suitable site has been purchased by the Government adjacent to the picturesque national reservation known as Rock Creek Park in the northern suburbs of Washington, a locality free from mechanical and electrical disturbances. Plans are being prepared for a physical laboratory which will be equipped with apparatus and conveniences for carrying on investigations and testing standards and measuring instruments of all kinds, and a smaller building to be known as a mechanical laboratory which will contain the power and general electrical machinery, the instrument shop, refrigerating plant, storage batteries, dynamos for experimental purposes, and laboratories for electrical measurements requiring heavy currents.

These laboratories will be constructed immediately, but the plans are being made with reference to the future growth of the Bureau, which will soon become one of the most important scientific institutions of our Government. The plans will include at least four buildings in addition to those now provided for.

The scientific work of the Bureau will be under the immediate supervision of a director, assisted by a corps of physicists and chemists designated as laboratory assistants, assistant physicists or chemists, and physicists or chemists with salaries ranging from $1,000 to $5,000. These salaries are somewhat more liberal than the Government has hitherto paid the scientific men in its employ. These men have been carefully selected by civil service examinations prepared with reference to the kind of work to be undertaken. No attempt has been made by politicians or others to influence the appointments in the Bureau, and the

Bureau once established upon this basis will, it is believed, be free from political influence. The Senators and Representatives who were instrumental in the passage of the bill would first of all resent any interference with the selection of these men upon any other basis than merit. To guard against any possible contingency of this kind, the law provides for a visiting committee composed of prominent specialists, each serving for a period of five years. The members of the present Visiting Committee were appointed to serve for periods of one, two, three, four and five years respectively; but their successors will be appointed for the full period. The committee consists of President Ira Remsen, of John Hopkins University; President H. S. Pritchett, of the Massachusetts Institute of Technology; Prof. Elihu Thomson, electrical engineer; Prof. Edward L. Nichols, Professor of Physics in Cornell University, and Mr. Albert Ladd Colby, metallurgical engineer. This committee, composed of men of world-wide reputation, will be consulted in all matters pertaining to the organization of the Bureau, and its existence ensures the establishment of an institution of the highest type.

The value of such an institution has been clearly demonstrated by nearly every government of Europe. England has established a standards department of the Board of Trade, also the electrical standardizing laboratory, and recently a physical laboratory; Kew observatory, an institution famous for its testing of meteorological instruments, has also become a Government institution. Germany has established the Normal Aichungs Commission, with its laboratories and facilities for handling commercial weights and measures, and in 1887, the Physikalisch-Technische Reichsantalt, an institution costing more than a million dollars, which makes provisions for scientific standards and investigations. It has been frequently said that this institution more than pays for itself annually in the assistance it gives to German manufacturers and scientists. The scientific work of our own Government has received great benefit from this institution during recent years. At the hearing before the House Committee on Coinage, Weights and

Measures in reference to the Bureau of Standards Bill, the Secretary of the Treasury presented letters from every scientific bureau in the Government, stating that they were compelled to go to this institution for certain standards. It was this fact, coupled with statements to the same effect from the prominent manufacturers, scientists and others present at the hearing, that led the committee to report unanimously in favor of the bill establishing the bureau. There is scarcely an interest in the country which will not be vitally benefitted by this new institution. Its relation to foreign commerce will be far-reaching, and its establishment means that the United States has taken a long step forward in the international race for commercial supremacy.

The Secretary of the Treasury, in his statement to Congress of the conditions necessitating the establishment of a National Bureau of Standards, made the following statement, which is worthy of our deepest consideration: "There is another side which occurs to me: it may appear to many to have a more sentimental than practical value, but it gives the proposition to my mind great force, and that is what might be called the moral aspect of the question; the recognition by the Government of an absolute standard, to which fidelity is required in all relations of life affected by that standard, is greatly to be desired. We are the victims of looseness in our methods, of much looseness in our ideas, too much of that spirit born out of rapid development and perhaps of a disregard or lax comprehension of the binding sanction of accuracy in every relation of life. Now, the establishment of a bureau like this, where the Government is the custodian and the originator of these standards of weight and measure as applied to all scientific aspects of life in which we are rapidly developing, has, to my mind, a value far above the mere physical considerations which affect it, although these physical considerations are fundamental and most important. Nothing can dignify this Government more than to be the patron and founder of correct scientific standards and such legislation as will hold the people to faithfully regard and obey the requirements of law in adhesion to those standards."

Whatever may be said of the advantages to be gained by the adoption of uniform and correct standards in any country applies still more in regard to uniformity of standards between nations. The introduction of modern methods of transportation and communication have brought the countries of the world into closer relation than were the counties of Great Britain a century ago, and while the question of a universal system of weights and measures has been discussed for many years, the adoption of such a system has become a necessity at the present time.

The choice of the fundamental standards for this system is a matter of convenience, but that it be a decimal system is of paramount importance. The meter may be no better than the yard, but the metric system is a decimal system, and has been adopted by all civilized countries except our own and Great Britain, and in the latter it has received a favorable report by the Parliamentary Committee having the subject under consideration, and it will undoubtedly be adopted by that country in the near future.

For several years the advisability of adopting the metric system of weights and measures as the standard of our country has been considered by Congress, and several bills have been favorably reported upon by the committee to which they have been referred. Some of these reports show a most thorough comprehension of the subject and set forth many urgent reasons why the metric system should be adopted.

The House Committee on Coinage, Weights and Measures, of which the Honorable James H. Southard, of Ohio, is chairman, has given a great deal of attention to this subject, and will undoubtedly present to the coming Congress a bill looking forward to the adoption of the metric system, and it will unquestionably be one of the leading measures discussed by that body. It should be stated that the passage of the Act establishing the National Bureau of Standards was largely due to the efforts of this committee, and especially of its chairman.

There is no denying the fact that a change in the weights and measures of the country will involve temporary con-

fusion and expense, but can it even be adopted with any less expense or inconvenience? There is no doubt in the mind of any thinking person but that a universal system must soon be adopted, and no system offering advantages equal to that of the metric system has yet been devised.

## AMERICAN ELECTRO-CHEMICAL SOCIETY.

From the *Electrical World* we learn that a movement was recently initiated, having for its object the founding of a national Electro-Chemical Society to be modelled on the same general plan as the American Institute of Electrical Engineers. The products of electro-chemical industries in this country at the present time amount to $100,000,000 per year. The growing importance of these industries and the fact that scientists and engineers interested in electro-chemistry are now distributed among at least half a dozen different societies, and heretofore have had no common medium of communication, are considerations which are believed to fully justify the movement. As noted at the time in our columns, a preliminary meeting in the interest of such an organization was held November 1st at the Engineers' Club of Philadelphia, Professor J. W. Richards, vice-president of the American Chemical Society, acting chairman and Mr. Carl Hering, past president of the American Institute of Electrical Engineers, as secretary. All those present were heartily in favor of forming such a society, and numerous encouraging letters were received from all parts of the country, those from representatives of the electro-chemical industries being especially favorable. It was unanimously decided that such a society should be founded as soon as a sufficient number of members could be secured to insure success. Committees were appointed to secure members and to arrange for a meeting in the near future, at which the society will be formally organized. It was the opinion of those present at the preliminary meeting that the annual dues for membership should not exceed $5, and that there should be only one class of members. Those who desire to become members of the society may send in their adhesion to Dr. Charles A. Doremus, 17 Lexington Avenue, New York City, chairman of the committee on membership.

## ELECTRICITY ON SHIPBOARD.

It is intended to utilize electricity in lieu of steam for subsidiary purposes upon the vessels of the English navy more extensively than at present. A series of prolonged experiments are to be made to ascertain the range of the practicability of using this power for this purpose. At present the capstan, steering engines, ventilating fans and derrick hoists on the vessels are manipulated by steam, necessitating the construction of a bewildering network of pipes in the interior of the ship. The new armored cruiser "Hogue" is being fitted with electric wires, and the entire subsidiary gear will be controlled by electricity. Should the experiment prove successful, the system will be extended to all other vessels refitting, as well as those under construction. A modern English battleship now carries a small staff of electrical engineers, so that no alterations will have to be made respecting the crew. W.

# Mining and Metallurgical Section.

*Stated Meeting held April 10, 1901.*

## THE INSPECTION AND TESTING OF CEMENTS.

BY RICHARD L. HUMPHREY,
Member of the Institute.

(*Concluded from vol. cliii, p. 42.*)

### RECORDS.

There should be some system under which the tests are made; that is, there should be a regular number of briquettes made from each sample, and they should be broken at regular intervals; whenever possible these tests should be extended beyond the regular twenty-eight day period, as it is very desirable to know what the strength is at the end of several years. In addition to the tensile tests, each sample should be submitted to all the tests usually employed. The data obtained from these tests should be carefully recorded in a book kept for the purpose. At regular intervals the data obtained should be compiled in tabular form showing the average tests.

### INTERPRETATION OF TESTS.

Having made the above tests, the interpretations of the results obtained is the next and most serious difficulty which confronts the inspector. It is impossible always to insist on a rigid compliance with the requirements of the specifications, since the failure to meet these requirements may be due entirely to faults in the testing. For example; if a cement was finely ground and yielded high neat tests, but was deficient in the tests with standard sand, it might be reasonable to suppose the sand tests were not properly made, or that the sand used was of poor quality. Again, if the fineness and tensile strength with sand were above the

requirements and the cement failed in the neat tests, it might be due to an excess or deficiency of water used in mixing, or it might be occasioned by the drying out of the briquettes, or they may have been affected by the conditions under which they were preserved.

It often happens that the person who makes the tests does not use the same amount of energy in each test; this is particularly the case where the number of tests made is large.

In cases where the cement fails to meet the requirements, it should be given a retest before condemning it.

## CONCLUSION.

Our methods of testing still leave much to be desired.

The elimination of the personal equation and the adoption of methods by which uniform and comparable tests can be obtained, are matters of vital importance which are claiming the attention of all those identified with the production and use of cement.

There are a number of committees of the International Association for Testing Materials, engaged in investigating various phases of this question and it is expected that some valuable reports will be forthcoming at the congress to be held at Budapest in September of the present year.

Numerous laboratories, both municipal and private, in this country, and the laboratories of the Ponts et Chausses, in France, the Royal Testing Laboratory at Charlotten burg, Germany, the Testing Laboratory at Zurich, Switzerland, and others on the continent, are engaged in the investigation of this subject, and it is not improbable that some definite conclusions will be reached in the near future.

The researches of Vicat, Pasley, Grant, Le Chatelier, Candlot, Michaelis, Tetmajer, Newberry and others, have brought forth valuable tentative deductions; but all of these deductions are yet susceptible of proof.

The complexity of the compounds formed during the process of hardening render any synthetic work on this subject very difficult, particularly so since these compounds

are radically effected by variations, in the composition of the raw materials, or in the burning. As has been already stated, it is impossible to tell just what changes take place during the process of hardening.

While the methods of manufacture now in vogue in the modern American Portland cement factory are unquestionably carried out with extreme care, and the greatest pains are taken to produce the best and most reliable cement possible, yet the value of these methods has yet to be demonstrated. Nor has the value of our methods of testing and the relative importance which we give to the various tests been established.

We should bear in mind that the present rotary kiln product is a comparatively new article, with whose properties we are only partially familiar. We do know that this cement hardens very rapidly and develops great strength in a very short time.

I have observed, and I have no doubt that other engineers will agree with me, that there is a period in the hardening of these cements when the tensile strength falls off very seriously. When this phenomenon came to my notice, it was confined entirely to neat cement; but latterly I have observed a decrease in strength of the sand mixture, although to a lesser degree.

Whether this action can be ascribed to fine grinding, overliming, hardburning or to the addition of sulphate of lime is very difficult to say. I have not observed the same falling off in compressive tests. It is noticeable in making long time tests of cement manufactured six or eight years ago, that the fracture of the briquette is very brittle, frequently shattering into numerous pieces.

Of the 60,000 and more briquettes which have been broken by myself or under my direction, the tensile strength of the neat cement did not exceed 1,100 pounds per square inch.

This strength is attained by Portland cements at the end of a long or short period of time, depending on the process of manufacture.

The great strength attained at a very early period by the

cement manufactured in these later years, is due, no doubt, to the fine grinding of the raw material and finished cement and hard burning. This strength is further increased during the early stages by the use of sulphate of lime.

The period of apparent retrogression is claimed to occur when the effect of the sulphate is neutralized, and that the real strength due to the formation of the silicates still continues.

The briquettes which show a loss of strength are perfectly sound and hard, and present no evidences of unsoundness or disintegration.

The chemical composition and the physical condition of the product of the modern rotary kiln process is such that the crystallization or hardening can take place in a very short period of time.

This process consists, briefly, in grinding the ingredients composing the raw mixture, from which Portland cement is made, to an impalpable powder and passing this powder through a rotary kiln where the intense heat (which enables the requisite chemical reactions to take place) converts it into a clinker. This clinker is in turn reduced to a powder so impalpably fine that when water is added to it the process of crystallization or hardening is started, which eventually converts the mass into stone.

We are enabled, therefore, through the perfection of this process, to artificially produce, in a very short period of time, that which nature requires centuries to accomplish.

During the early stages of this phenomenon the mass is in a tough and more or less amorphous condition, and the tensile strength is high; but as the crystallization proceeds, the mass becomes more brittle, and increases in compressive strength. It seems to me that this loss of tensile strength can be attributed to crystallization; and I think that the reason the loss is not greater in the case of sand mixtures than neat cement is, that the voids in sand mixtures enable the expansion, produced by the process of crystallization, to take place with less injury to the adhesive qualities of the cement. It should be remembered that stone is tested in compression; we do not think of testing

it in tension. It would seem logical, therefore, to test the hardened mass of cement mortar or concrete in compression. This, in my opinion, is the proper method for ascertaining the real strength of cement, especially at the end of a long period of time.

Tension tests should be used for the purpose of determining the relative value of shipments of cement, and should be confined to tests not extending over twenty-eight days.

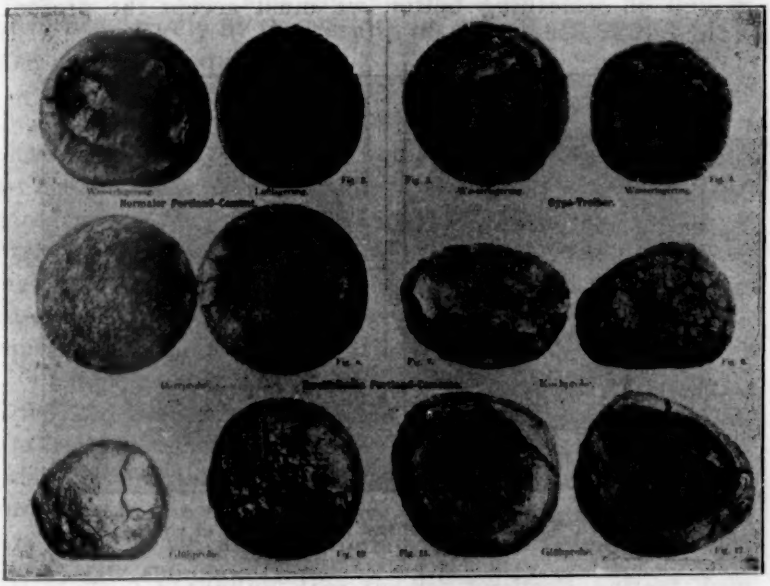

PLATE XXI—Result of tests for constancy of volume.

Whatever may be our doubts on the subject, and notwithstanding the obscure points yet to be explained, the fact remains that the masonry and the concrete in which the modern Portland cements have been used show no signs of deteriorating, but, on the contrary, show increasing hardness. And it is especially noticeable (when it is necessary to tear out portions of the structure) that the cement mortar is frequently stronger than the stone or other material which it binds together.



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I do not know of an important piece of work (in which the cement was tested and accepted) where the failure of the Portland cement mortar or concrete used in its construction could be ascribed to the bad quality of the cement.

The late John McAlpin is credited with the statement that the only way to test cement is to wait fifty years and see whether the structure still stands.

We will unquestionably have to wait in order to prove the correctness of our present theories. In the meanwhile, in lieu of something better, we must accept the present

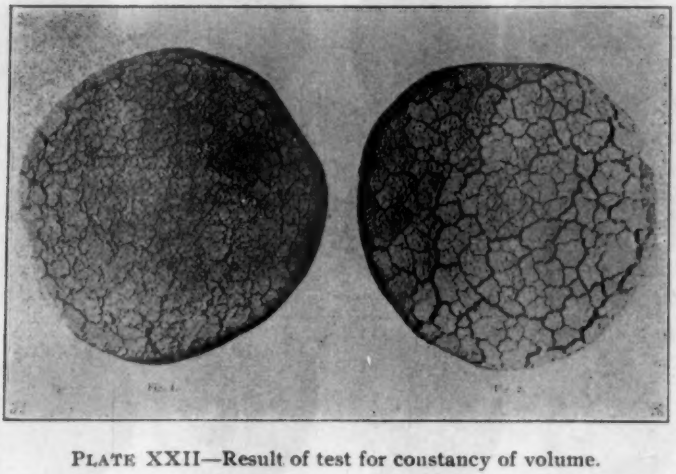

PLATE XXII—Result of test for constancy of volume.

high testing Portland cement with unlimited faith in its high excellence as a building material.

History teaches us that engineers prior to 1756 and subsequently, who used lime mortar, were compelled to frequently renew the mortar in the structures in which it had been used on account of its being washed out of the joints. While it is true there are structures built thousands of years ago in which the mortar is exceedingly hard, nevertheless we have reason to believe that it required centuries to acquire this hardness.

On the other hand, we do know that the modern Portland cement can be depended upon to develop great

strength in a very short time. This is a feature of great importance in our present methods of rapid construction; and we further know that thus far the cement has withstood all normal forces tending to destroy it.

Having consented to accept the cement on faith, we should not be too rigid in testing it, especially in the absence of any infallible system by which to gauge its quality.

The system used in inspecting and testing cement should be a rational one, and the interpretation of it should be governed largely by the results of experience, rather than by theoretical requirements.

DISCUSSION.

MR. ROBT. W. LESLEY:—I have listened with great interest to Mr. Humphrey's remarks, and having, in 1898, prepared a paper which I read before the Engineers' Club, of Philadelphia, on the same subject, it is gratifying to know that the world "do move," as shown by the new facts and later experiences adduced by the writer of to-night's paper.

There is no question that "from the moment the clinker is reduced to impalpable powder its physical and chemical qualities are constantly undergoing changes which affect its quality as a building material;" "and even after it is made into mortar, these changes are constantly going on." In this country we are confronted, as Mr. Humphrey well states, with the manufacture of Portland cement by what is known as the rotary process, and we have enormous amounts of work done with material of this character, which, as yet, has to prove itself by the tests of time, the equal of cement made in the old-fashioned way with dome kilns. So far, experience has shown that this rotary cement is meeting all the requirements, though the results in long time tests seem to indicate that the maximum of strength is reached at an earlier period than in the dome kiln cements, and it remains for the tester and experimentor of the future to determine whether this lack of gain in strength at long periods is due to any deterioration in the material itself, or is due to a lack of elasticity caused by the material attain-

ing its greatest strength and highest crystallization at the earlier periods.

After all, however, whether the cement be made by the rotary kiln process or be made by the dome kiln process, cement is always tested in a different condition from that in which it is manufactured. The cement briquette is a new material, and is not the material that the manufacturer ships to the work; and, therefore, the testing involves the greatest skill, the greatest fairness and the greatest judgment in coming to conclusions.

All other materials are tested as finished products, while cement is tested in the form made by the tester, and not by the manufacturer, and the test is the result of the cement, plus the experience of the tester, plus the variations of water, temperature and laboratory conditions. It is to obviate these that the tester must devote his highest talents. The nearest approach to fairness in this direction is for the testing to be done at the place of manufacture, wherever the contract is large enough to warrant such conditions.

The most recent illustration of this method is that practiced by the Rapid Transit Commission of New York, which has introduced this system to its fullest extent on their work in the city of New York.

By arrangement with the general contractor and the cement manufacturer, it is provided that all the cement for that work shall be tested at the place of manufacture; that it shall be run into bins subject to the inspection of the testing department of the Rapid Transit Commission; that there shall be on hand a sufficient quantity of cement to admit of twenty-eight days' test; and that the cement, after the bin has been accepted, shall be placed in bags and sealed with the seal of the Rapid Transit Commission, indicating on the seal the date of the shipment and the number of the bin. It is further provided that this cement shall be sent to the warehouse of the cement company in Jersey City, and at that point sufficient supply of this cement, sealed as above, for at least a week's operation, shall be held. From this warehouse deliveries are made on the work in the sealed packages.

Under this method the inspectors of the Rapid Transit Commission have their own building, provided by the manufacturing company, with their own chemical and physical laboratory provided for them for the purpose of making all their own tests; they have full access to the mills of the company; privilege in examining the raw materials; the mixtures made; the grinding, and sample the cement from day to day as it is ground, thus measurably controlling the product that is intended for their use.

After the cement has been thus tested, it is then ready for use on the work, and it can readily be seen that an immense saving is effected to the contractor by obviating all necessity of storing cement pending test in the crowded city of New York, and that further, the cumbering of the streets of New York with thousands and thousands of barrels of cement awaiting test is thus clearly obviated.

Under this method, the best results have been attained. The cement has shown itself equal to any of the requirements of the specification, and the actual physical results have been remarkable: so remarkable in fact, that in one case, two walls 175 feet long, 15 feet high at one end and sloping down to one foot at the other, forming two sides of a double-track railroad, were each moved without break a distance of four feet back from original foundation in order to widen the roadbed at that point to admit of a four track railway.

Such a method as this, where coöperation can be had between the inspector and manufacturer, and the consumer and the producer, eliminating the difficulties that have frequently occurred by the variation of the personal equation in the testing at a point distant from the work, of the new material known as the briquette, has obviated many of the difficulties that have hitherto arisen, and is to be highly recommended wherever the work is large enough to warrant the establishment of such a laboratory or the testing in such a way. It can only be done successfully in large contracts, 10,000 barrels and over, small amounts not warranting the outlay.

The testing of cement certainly should be done in the

simplest way, as the purpose is not the establishment of standards, but the ascertainment that a brand of established reputation, which has been adopted for the execution of an important work, will come up to its own standard. It is not for the ascertainment of the varying qualities of various brands, but is for the ascertainment of the fact whether or not the manufacturer of the accepted brand has or has not "put all his big strawberries on the top of the basket" in sending the first sample that he puts into the work.

Assuming that a brand of well-established reputation (and there are many in the market) has been selected for the work, there is no question but that chemical analysis to determine that this brand as manufactured is of a suitable character has great value, and for purposes of verification such analyses should be made from time to time during the progress of the testing.

*Fineness* is an element that is within the control of the manufacturer, and is a question of machinery and care, and under the specifications can usually be obtained. In my own experience, the only question that has ever arisen as to fineness has come about through misunderstandings, not as to the fineness of the cement test but as to the character of the sieve through which the fineness is to be determined. It may be a strange statement to make, when I say that upon a recent occasion where a certain fineness through a 100-mesh sieve was required, that out of some eighteen 100-mesh sieves purchased in various parts of the country, or procured from various cement works and testing laboratories, no two were alike, and no two were actually 100 x 100-mesh sieves. Upon investigation it was ascertained that these sieves are woven by hand with great labor, and that in the single piece of wire-cloth out of which a number of sieves may be made, very material variations occur, owing to the drawing of the sieve on the loom, owing to the carelessness of the man at the loom, or owing to the pulling of the cloth at the time of putting it over the sieve itself. Generally speaking, a 100-mesh sieve will measure about 96 x 100, and this is what may be for

all practical purposes considered to be a 100-mesh sieve. Other difficulties in fineness may occur by the sieve becoming choked with fine dust, thus not allowing the material to go through. and as stated by Mr. Humphrey, by slight tears or holes in the sieve which permit an excess of coarse material to pass through.

What has been said with reference to the 100-mesh sieve applies much more to the 200-mesh sieve, where all the difficulties are aggravated. Moisture is the cause of many failures to obtain the requisite fineness from the extremely fine sieves, but this can be obviated by drying as stated in the paper.

At Professor Tetmajer's laboratory in Zurich, probably the best mechanical sieves are to be seen, the operation there being from one sieve to another, and the whole being moved by steam power.

Without desiring to be radical or to institute new theories it has been my privilege to see—and I understand the figures will be shortly published—a series of tests of re-tempering mortars of natural and Portland cements. These tests, conducted by one of the most prominent engineers in the country, give results of mortar re-tempered at the end of an hour, at the end of two hours, and kept constantly in the condition of tempering for a period of two hours. From them, as shown by the result of the briquettes, it would seem that the whole question of re-mixing and re-tempering mortars has not been thoroughly understood, and further, that it might be concluded that the actual question of time of setting is not so important or vital a one as has hitherto been supposed. Of course, common experience itself shows that re-tempered mortar is not as good as the original mortar, but in the face of these later figures, which certainly will create considerable interest in the engineering profession, it would seem by scientific tests on this subject that there is considerable ground for doubt as to the whole present knowledge on the subject of re-tempering mortars and of the whole value of tests for time of setting, so far as practical experience is concerned. This time of setting, however, is always an important factor in

the manufacture of briquettes and in the manufacture of sample pats because, without the ascertaining of this condition, many briquettes and many pats would be put into the water long before the period at which the actual setting had occurred, with the certain result of causing their disintegration.

Too much stress cannot be laid on the question of the percentage of water to be used in making the mortar. This will materially affect the percentage of gain that cements will show between the seven-day and twenty-eight-day tests; as small a difference as 1 per cent. in the water will cause variations of from 10 to 15 per cent. in the ratio of gain between the periods above stated; the wetter moistures show the greater percentage of gain, while the dry mixtures show little or no increase in strength. The percentage of water is a factor that cannot be determined once for all with every cement, but is one that must be felt for tentatively from time to time in the testing.

In a laboratory where a boiling apparatus or steaming apparatus is in operation, and samples are laid on shelves, it is a frequent case for the cement powder to absorb a considerable amount of moisture; and in such cases where the percentage of water to be used has been passed upon the dry sample, it can readily be seen that such a percentage would be in excess if the sample was subjected to moistures. On the other hand, where the water is very hot and the cement from the mill contains the latent mechanical heat of grinding, or where the testing-room is absolutely dry and no moisture is in the air, a cement to which a certain percentage of water has been allotted will, under these conditions, obtain too little water for its best development or manufacture into pats or briquettes. While, therefore, there is no question as to the advantage of having a formulæ such as the speaker gives for dealing with this subject, yet these formulæs would still be subject to the variations above mentioned. On the other hand, the practice described by the Testing Station at Charlottenburg of determining the percentage of water to be used by mixing the cement to a syrup paste so that it will run from the

knife in long thin threads without forming into lumps, would seem to indicate, though in itself only a "rule-of-thumb" method, a means of everyday practice that might yield the better results.

In the paper which I read before the Engineers' Club, of Philadelphia, I gathered some 200 odd specifications of various engineers in charge of Army, Navy, public and private work, and showed the general trend of specifications, and what was required by these many men of many minds. It is a source of gratification to find that the present period shows that within the last three years there is a trend—first, toward the standardization of tests, and second, toward the discarding of many of the abnormal seven-day tensile-strain requirements that form parts of some of the older specifications. The recent report of the Board of Engineering Officers to the Chief Engineer of the United States Army shows a most important step by a most important branch of the Government toward this unification of standards; and the seven-day requirements there adopted are fair, and can be met by the average of American Portland cements without running the risk of over-plastering or over-liming. The Navy Department has under consideration a standardization of their various specifications, and it is to be hoped that these two important branches of the Government, doing millions of dollars' worth of work a year, will come to some uniform and general standard, both of methods and of requirements, that will take out of consideration both of engineers and manufacturers the hundreds of specifications of varying characters that have hitherto been before the public.

If it were possible for the Committee on Cement of the American Society of Civil Engineers to correlate in their work with these two branches of the Government service, cement manufacturers would be only too glad to lend a willing hand toward the production of a uniform specification, such as exists all over Germany, where the German Government and German engineers are actually represented and take part in the proceedings of the German Cement Makers' Association.

As a digression from so serious a topic, I would say that I agree entirely with Mr. Humphrey in the fact that hand mixing is the best and most satisfactory method of making briquettes; and while I note the various machines he describes for the purpose of mixing, he missed one which afforded me a great deal of amusement, viz., the milk-shake apparatus which was used on the Chicago drainage canal. In the laboratory there, four men were employed in the making of briquettes: one prepared the raw material; one added the water; another operated a milk-shake apparatus in which water and cement were rapidly whirled around; and a fourth man took the paste and put it in the briquette molds. This application of a very simple arrangement produced very good briquettes and fairly good results.

At the time of making the briquettes too much consideration cannot be given to the temperature of the room, to have it uniform and to have the air moderately moist. The variations in the manufacture of briquettes have been well ascertained in some experiments by Prof. J. Madison Porter, of Lafayette College, who collated them and gives his results in the *Engineering News*, March 5, 1896. They are given in the accompanying table, and indicate how important it is to have the briquettes trowelled on both sides, and to have uniformity in the mixing and moulding of briquettes.

Just as it is a pleasure to one who has struggled with cement and cement testing for twenty-seven years to see a swing of the pendulum in the matter of rational requirements in tensile strains at seven and twenty-eight days, as contradistinguished from the high specifications that were eliminated a short period ago, so it is equally gratifying to find men who have had the experience of Mr. Humphrey—Professor Dow, of the Washington Laboratory; Colonel Powell, of Pittsburg—abandon the radical boiling test for constancy of volume. The indiscriminate use of the boiling test is doing more harm than good to the cement consumer, for, while this test is the *bête noir* of the cement manufacturer, he is forced to use sulphate of lime to the possible detriment of the cement, and this is to overcome the *bête noir* that has been put in his path unnecessarily.

TABLE SHOWING RESULTS OF TENSILE TESTS OF MORTAR, ONE PART CEMENT, THREE PARTS SAND (SAME SAMPLE OF CEMENT) MADE BY DIFFERENT PERSONS IN ACCORDANCE WITH THEIR UNDERSTANDING OF THE METHOD PROPOSED BY THE COMMITTEE OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

*(Extract from Article by J. Madison Porter, Engineering News, March 5, 1896.)*

| Laboratory. | Tensile Strength in Pounds of Briquettes. | | | | | | | Range in Pounds. | Ratio of Range to Maximum. | Ratio of Average to Maximum. | Water Per Cent. | Molds. | Struck Off. | How Placed in Water. | Water-bath. | Kind of Machine. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 1. | No. 2. | No. 3. | No. 4. | No. 5. | No. 6. | Av. | | | | | | | | | |
| 1. R. W. Hildreth & Co., New York | 68 | 72 | 74 | 78 | 82 | — | 75 | 14 | 17·1 | 30·4 | 12 | Single. | Both sides. | Flat. | Still. | Riehlé. Driven by hand. |
| 2. Washington University, J. B. Johnson | 77 | 94 | 108 | 110 | 122 | — | 102 | 45 | 36·9 | 41·8 | Not known. | Gang. | One side. | " | " | Fairbanks. Johnson's clips. |
| 3. City of Easton, H. R. Fehr, England | 106 | 112 | 123 | — | — | — | 114 | 17 | 13·8 | 46·5 | 10·4 | Single. | Both sides. | Edge. | " | Fairbanks. |
| 4. Columbia College, W. H. Burr | 125 | 126 | 130 | 137 | 140 | 144 | 133 | 19 | 13·2 | 54 | 10 | " | One side. | Flat. | " | Riehlé. Driven by hand. |
| | 126 | 132 | 138 | 144 | 150 | 153 | 140 | 27 | 17·7 | 56·8 | 8 | " | | | | |
| 5. C. F. McKenna, New York | 148 | 150 | 151 | 155 | 160 | — | 153 | 12 | 7·5 | 62 | 12 | " | Both sides. | " | " | Riehlé-McKenna. Rubber clips. Power driven. |
| 6. Cornell University, F. P. Spalding | 155 | 160 | 164 | 166 | 174 | — | 163 | 17 | 9·9 | 66 | Not given. | " | One side. | Edge. | Running. | Lever with bucket. |
| 7. Lafayette College, J. M. Porter | 171 | 177 | 177 | 178 | 179 | — | 176 | 8 | 4·5 | 71·4 | 11 | Gang. | Both sid s. | " | " | Olsen-Porter. Porter's clips. |
| 8. Clifford Richardson, Washington, D. C. | 220 | 224 | 226 | 228 | 228 | — | 225 | 8 | 3·5 | 91·2 | 10 | Single. | Both sides | Flat. | Still | Riehlé. Driven by hand. Rubber clips. |
| 9. Booth, Garrett & Blair, Philadelphia | 240 | 246 | 249 | 250 | 252 | — | 247 | 12 | 4·8 | 100 | 12 | " | Both sides. | Edge. | " | Olsen Power driven Rubber clips. |
| Average | — | — | — | — | — | — | 153 | 17·9 | 12·9 | 62 | 10·8 | 77·8% single; 22·2% gang. | 66⅔% both; 33⅓% one. | 55·5% flat; 44·6% edge. | 22·2% running; 77·8% still. | 66⅔% power; 33⅓% hand. |

No. 2, water in bath changed once. No. 5, water not changed. No. 6, flow of water just sufficient to keep it fresh. No. 7, flow of water slight. No. 8, speed applied, 35 to 40 pounds per minute.

All molds and sand American Society of Civil Engineers' recommended sizes.

In a paper written by me, in discussion of Lewis & Whitfield's paper (*Am. Soc. C. E. Proceedings*) October, 1894, I scrutinized some seventy-four boiling tests that had been made under all the accelerated tests known in Germany, and taking those cements that had boiled and had stood the accelerated tests, I showed conclusively that in every case these cements contained an excess of lime or sulphate of lime, thus proving conclusively the point advanced by the speaker to-night.

Considering only what Mr. Humphrey himself states as to the manufacture of the pats to be subjected to his suggested test of 170°, and considering what he has to say on the things that are to be observed under this test, it would seem that possibly the simple normal test of the Germans would more fully comply with Mr. Humphrey's desired system of testing, viz.: "I am not in favor of any system which depends on cumbersome methods or expensive apparatus. The number of tests should be few, and simple in execution."

This whole question of hot tests, boiling tests, steaming tests, etc., has been gone over and over and over again by cement authorities all over the world. Faija, the pioneer, started it, advocated it and pushed it to the fullest extent, and yet, at the Engineering Congress at the Chicago World's Fair, publicly acknowledged that he was wrong. The Germans, with their careful and painstaking methods, have produced a half dozen various tests or methods of accelerated tests for determining the constancy of volume of Portland cement. For years, to my knowledge, they have been investigating this subject, and the Royal Testing Bureau at Charlottenburg, the various representatives of the various departments in Germany have, in connection with the German Cement Makers' Association, been laboring on this subject. Four years ago a committee was appointed to go over it thoroughly and conclusively. It was vested with full powers to probe the subject to the bottom, and after two years of experimenting they made their first report through Max Gary, Director of Division of Tests of Construction of the Technical Laboratory at

Berlin, and this report, just made in the contributions of the Royal Laboratory at Berlin, was presented at the German Cement Makers' Association meeting in 1899. On the strength of it, an *ad interim* report was made by the committee above stated, as follows:

"*Final Conclusions:* The result of the investigation may, therefore, be summed up as determining that none of the so-called accelerated tests for constancy of volume is adapted to furnish a reliable and quick judgment in all cases concerning the practical applicability of a cement. The investigation has further proved that all ten cements which withstood the pat test in the normal system of testing are practically constant in volume when used in test pieces and cement wares. The increase in strength of the test pieces with water- and air-hardening speaks well for the practical utility of the cements.

"The assertion quoted early in the report that the normal or standard tests were insufficient, particularly when the cement is to be hardened in the air in its practical application, has received no confirmation by the investigation of the commission. Nevertheless, the commission is ready to carry out still further investigations, and requests the sponsors for the accelerated tests for soundness to provide sufficient quantities of such cements as pass the normal tests, do not satisfy the accelerated tests, and prove unsound in practical service. The cements should be sent to the Royal Testing Laboratory until October 1, 1900. Until it has been possible to discover a test for soundness which is reliable and can be carried out in a shorter time than the standard test, the pat test of the normal specifications must be retained as decisive."

Two years have gone by since this report, and at a meeting of the German Cement Makers' Association, held in February of this year, the Committee on Accelerated Tests, made a further report, which says:

"After having made tests up to the length of two years, the commission for deciding as to the constancy of volume and adhesive power of Portland cement came to the conclusion that none of the so-called accelerated tests (boiling

tests, etc.) were capable in all cases of affording a quick and reliable judgment in regard to the practical usefulness of a cement.

"Last year those tests ended, after four years, and Mr. Max Gary, of the Royal Testing Laboratory at Charlottenburg, has published the results of those tests as were made by his department, and also by the above-mentioned commission, in the 'Communications from the Royal Testing Station,' the main contents of which are as follows:

"Even the four-year tests have confirmed the results and conclusions of the two-year tests; neither the four years' observation, nor measuring the expansion, nor the firmness of the 10 cakes tested, and that were not considered up to the standard, justified us in declaring those cements useless for practical purposes.

"This is confirmed by pieces of cement-ware made of this same cement, and which have lain these four years in the open air. (They are on a frame 4 meters high and exposed to the influence of the weather. Rain and snow can collect in deep places, while protruding places are dry; the influence on the surface, therefore, is very unfavorable). Yet those objects did not show, during those four years, changes that amount to anything. Small flaws that were observed after the first four months are only on the surface, and appear with even the very best cement in the open air.

"Therefore, the commisson must refute as wrong, based on those tests, that the accelerated tests as to the constancy of volume allow a better judgment as to the usefulness of cement than the normal tests, and the normal tests must therefore be kept as the deciding tests for the constancy of volume of Portland cement.

"Another point has to be touched: In the report two years ago, the commission declared itself willing to make further tests, and publicly invited those persons recommending accelerated tests to produce in sufficient amount such cements as pass the normal test but do not pass the accelerated test, and which expand during practical use. Though the said parties had time until the first of October, 1900, to produce such cement, neither documents nor

samples have arrived at the Royal Testing Station nor the commission concerning such cement, so the commission considered its work concerning the constancy of volume ended."

After reading the report and hearing some discussion on the same, the following resolution was presented, viz.:

"*The assertion that the so-called accelerated tests for constancy of volume generally admits of a better judgment about the usefulness of cement than the normal test, must be refuted as wrong.*"

which was finally adopted, with but a single negative vote.

This expression of the German Society of Cement Manufacturers, which numbers among its members and has present at its deliberations the heads of all the important departments of public works in Germany, and the head of the German Testing Laboratory, would seem to be conclusive on this subject of accelerated tests; and it leaves as a test for constancy of volume the ordinary German normal test, which is as follows:

"Small pats of the cement are made, which are allowed to stand twenty-four hours in damp air, and are then placed, some in water and some in the air, and observed until twenty-eight days old. If they do not become distorted or cracked during this time, the cement is considered sound."

To my mind, therefore, it would seem that as we have all recognized the Germans as being in the fore-front of Portland cement manufacture, and representing the highest degree of scientific and technical knowledge, that it would be wrong for us to disregard the conclusion of such a body and the result of work of so serious a character covering a period as long as four years; and therefore, while I may say, as a result of my own experience, that most of our Portland cements boil; yet I do feel that, as a practical fact, following out Mr. Humphrey, that the best test is a *bête noir* to manufacturers, in the sense that it tempts them to adulterate and over-plaster; for the reason, I believe, that it is a test which might be omitted as a definite, positive, conclusive test, but might be used by the manufacturer for his own information in the manufacture of cement, and by the

engineer from time to time, as suggested in the Report of the U. S. Army Engineer Corps, for the purpose of informing himself as to the character of the material that is presented to him, but not as a conclusive test for the rejection of the material.

To the ordinary public it might seem that too much time and thought are wasted on this subject of cement testing, but it is one that is so serious in its results and so vital in its objects, in connection with the large buildings and works of all countries, that it cannot be disregarded; and it is gratifying to know that so eminent a society as the Franklin Institute should consider the subject as it has. As a former President of the American Society Civil Engineers, himself one of the most distinguished of bridge engineers in this country, said to me, "We are in the age of cement," and his conclusions are certainly right on this subject. The growth of the Portland Cement Industry in this country, from 1890 to the present year has been from 335,500 barrels to 8,482,020 barrels in 1900, or a growth of 8,146,520 barrels, and to all of us who are familiar with the subject, the growth of the literature has been even out of proportion to the growth of the product. There is no subject that is exciting among engineers, builders, and others so large an interest as concrete and cement in all its forms, and there is every indication that the coming century will see the flower of the cement age and the use of cement most general in all forms of construction.

A MEMBER:—Mr. Humphrey in your paper, among the tests for soundness, you did not mention the "Lamp-Chimney Test." I should like to know whether you regard the test as a valuable one?

MR. HUMPHREY:—The "Lamp Chimney Test" was in general use some years ago, and is still used in some laboratories. I do not regard the test as a rational one.

Practically speaking, all cements expand slightly upon hardening, especially the neat pastes. It is perfectly natural that they should. The formation of crystals in a supersaturated solution is characterized by a gradual increase in the volume of the crystalline mass. The hardening of

cement is said to be the result of similar conditions. Ordidarily the common lamp chimney is readily cracked by internal pressure; it is not surprising, therefore, that good cements fail under this test. Besides the commercial chimney varies considerably in thickness from the light thin type to the double thick or extra heavy kind. It is evident, therefore, that the chimney test as usually specified, without any stipulations as to the character or thickness of the chimney is very indefinite and unsatisfactory. Again the swelling of the neat cement by itself, if not excessive and accompanied by checking, cracking or other indications of unsoundness, is not dangerous. Inasmuch as cement is not used pure in actual work, but is mixed with varying proportions of sand, gravel and broken stone, whatever expansion there may be is usually taken up by the voids in these aggregates without producing any noticeable injurious results.

The test is not therefore adapted for practical use first, because it cannot be defined with sufficient accuracy to secure reliable results, and secondly these results, when obtained, furnish no positive information as to the soundness of the cement.

MR. F. L. GARRISON:—I should like to know whether any experiments have been made with the microscope? A great deal has been done with the microscope in the study of iron and steel, and it seems to me that it could be used in a similar manner in the study of cement.

MR. HUMPHREY:—The only microscopical work of importance, of which I have any knowledge, is that by Professor Le Chatelier, and was published in the *Annales des Mines* in 1891. This is a very valuable contribution.

Thus far no data have been obtained upon which to base a test for determining the quality of cement by the aid of the microscope. The difficulties attending the microscopical study of cement, the lack of proper facilities and time, especially the latter, are some of the causes which have prevented research of this character in permanent laboratories, at least in those in this country. This is practically an unexplored field of research.

DR. WAHL:—Did I not understand you to say, Mr. Humphrey, that the carbonization in lime mortars was only superficial. I should think that this carbonization would extend through the mass.

MR. HUMPHREY:—Chemical analysis of the mortars from ancient structures made by various persons, show that the amount of carbonization in these mortars is slight. An examination of the mortar shows that only the outer surface has become hardened, and that in many cases the heart of the mortar is quite soft, indicating that even after thousands of years this carbonization has not extended through the mass. The outer surface of the mortar becomes carbonated very rapidly, but the carbonization of the inner mass proceeds much more slowly.

S. F. PECKHAM (Correspondence):—On reading this exceedingly elaborate and valuable paper I find very little to criticize. There are, however, three points to which I wish to call attention.

(1) The method of chemical analysis, recommended by Mr. Humphrey, requires the fusion of one-half grain of the finely pulverized sample, dried at 100° C., with four or five times its weight of sodium carbonate.

I have elsewhere shown (*Journal of the Society of Chemical Industry*, June 29, 1901, vol. xx, page 539) that this method of analysis by fusion of the whole cement, after pulverizing and drying, gives more or less erroneous results, for the reason that pulverizing and drying destroys the identity of the specimen. If a cement that has been injured by absorbing water is dried before it is analyzed, the sample analyzed is not the sample submitted. If a badly ground sample is finely pulverized before it is analyzed, the sample analzyed is not the sample submitted. In both instances certain differences that may exist in the specimens that are submitted are obliterated in the specimens that are analyzed by pulverizing and drying.

The process of analysis recommended by Mr. Humphrey will commend itself in most respects as very admirable; yet, I believe it is based on a fundamental error. I do not believe that in the analysis of cement an ultimate analysis

is to be desired, and if had, is of much value as determining the comparative value of cements. Repeated analyses have shown that the more completely a cement approaches a theoretically perfect cement in its physical and chemical properties, the more completely it is soluble in dilute acids, including not only the mineral acids, but very dilute organic acids as well. A cement that contains grains of sand or overburned oxide of iron or underburned "mix," provided these constituents are found in the proper proportions, will give entirely satisfactory results upon ultimate analysis by fusion with sodium-carbonate. It is only when the cement is dissolved away from the inert impurities that the true character of the sample is revealed by chemical analysis.

(2) Mr. Humphrey recommends that for sieving, the sample should be heated to 130° F. Again, I claim that the sample should be tested as received. A sample of good cement is dry and fine, and sieves easily. If a sample is damp and lumpy, it should not be dried to make the labor and time of sifting less.

(3) Mr. Humphrey claims that if a finely ground cement makes high, neat tests and low sand tests the sand tests are not properly made. Such a conclusion is by no means legitimate. An unevenly burned sample may consist of good quality diluted with unburned "mix" or unburned cement-rock. Such a cement will test fairly high, neat and fail badly when mixed with sand, because, to start with, the cement is diluted with inert matter, and when it receives its proportion of sand it is heavily overloaded. Lime, as carbonate, is not cement, and when from 25 per cent. to 33 per cent. of a cement is calcium carbonate, the sample to begin with is practically from $\frac{1}{4}$ to $\frac{1}{3}$ sand.

This condition is not recorded by any of the tests recommended by Mr. Humphrey. Ultimate analysis by fusion does not touch it. It is found only by determining the loss at a red heat or by direct determination of carbonic acid. In my judgment, the determination of the loss at a red heat should now be omitted.

MR. HUMPHREY (Closure): The practice of inspecting

and testing cement at the place of manufacture has been in vogue for several years on important engineering works, among which may be mentioned, the Government work under Major F. V. Abbott at Lake Winnibigoshish, Minnesota; the dam and power-house of the Power Company at Sault Ste. Marie, and all constructions (requiring cement) along the lines of the Baltimore and Ohio and the Chesapeake and Ohio Railroads. As Mr. Lesley states, a recent illustration of this method is afforded by the practice of the Rapid Transit Commission of New York.

It is hardly necessary to state that as far as the quality of the cement is concerned, it is immaterial where the inspection and testing is done, provided the cement is not subsequently damaged.

The chief advantage of this method is that it avoids the extra handling of the cement delivered on the work, which would be the case where cement, submitted for inspection on the work, was rejected.

The successful moving of the two walls, as described by Mr. Lesley, should be attributed to efficient engineering rather than to the quality of the cement used, since any high-grade American Portland cement, properly used and allowed sufficient time to harden, would stand this test.

The importance of normal consistency cannot be too strongly emphasized. The percentage of water required to produce this consistency varies with each sample of cement. The percentage of water required to produce a plastic paste of normal consistency of neat cement with the various brands of Portland cement varies from 15 to 30 per cent. With natural cement the range is from 18 to 40 per cent.

The practice, therefore, of using the same percentage of water for all samples of cement of the same class is a vicious one, which cannot be too strongly condemned.

The "milk-shake apparatus" referred to by Mr. Lesley, was, I think, first proposed and used in the Testing Laboratory of the St. Louis Water Works Extension. This machine, shown on Plate VIII, *Fig. 1*, of this paper, was described in the article by Mr. S. Bent Russell, which appeared in the *Engineering News* of January 3, 1891. This

machine has the same defect as the other forms of mechanical mixers, viz., the impossibility of producing a paste without the cement "balling up."

Concerning accelerated tests for constancy of volume, I desire to state that I have never been in favor of the "radical boiling test" nor do I believe in its infallibility.

The German cold-water test is reliable, but on account of the length of time required to develop evidences of unsoundness by this method, it is of little practical value as a test of reception where the acceptance of a cement is based on the results of the seven-day tests. Mr. Lesley errs, I think, when he states that Faija, in his paper before the Engineering Congress at Chicago in 1893, abandoned his steam and hot-water test; his position, as regards this test at that time was the same as when he first proposed it.

With all the defects and objections to the test, I think, after mature reflection, it will be admitted by all that the general use of the "boiling" or "hot-water" test in testing-laboratories, both on the work and at the place of manufacture, has done more to improve the quality of the American Portland cements than any other test.

While I am not willing to endorse this test for general use, yet I do think that in the hands of the expert it is of considerable assistance in judging the quality of a cement.

Of the present methods for making the accelerated tests, I believe that the immersion of the pat (after twenty-four hours in moist air) in steam coming from boiling water, contained in a loosely closed vessel, to be the simplest test, and immersion in water maintained constantly at 170° F. to be the most reliable test. The duration of these tests should not exceed twenty-four hours.

The failure of a cement to meet the requirements of this test should not necessarily be cause for its rejection; it should, however, lead to a further and more careful investigation of its quality.

I believe there is urgent need for some form of accelerated test for constancy of volume, and trust that some method will be proposed in the near future which can be used by novice and expert alike with some degree of accuracy.

Concerning Professor Peckham's remarks, I desire to state that the object of the fineness test is to ascertain the thoroughness of the final pulverization of the cement at the mill, by determining the percentages of the grains passing certain standard sieves.

It would be impossible to make this properly with a cement which contained enough moisture to cause it to be "lumpy," unless these lumps were first reduced to a powder by drying.

Besides, since a thoroughly dry cement sieves much more readily, the preliminary drying renders the work of sieving far less tedious.

If a cement has absorbed sufficient moisture to cause it to become "caked," the fact is at once visible and is taken into consideration in the preliminary inspection of the cement. If the cement meets the other requirements this condition should not be sufficient cause for its rejection.

The adulteration of cement with "unburned mix" or "unburned rock," can be detected by determining the carbon dioxide; when the adulteration is to the extent stated by Professor Peckham, it can be detected by means of the specific-gravity test.

The practice of effecting a solution of the sample of cement for analysis by fusion with sodium carbonate of the thoroughly dried and finely pulverized sample is quite common, and is a most reliable way of decomposing the silicates.

When the quantity of clay or insoluble silica is desired it is determined separately.

At the present time it is an ultimate analysis that is required.

While Professor Peckham's theories as to the object of chemical analysis and his proposed methods for the examination of cements may be perfectly correct, their value is yet to be demonstrated.

# Mining and Metallurgical Section.

*Stated Meeting, held Wednesday, November 13, 1901.*

## UPON THE CONSTITUTION OF BINARY ALLOYS.

By JOHN ALEXANDER MATHEWS, PH.D.

*Continued from vol. cliii, p. 21.*

### MOLECULAR DEPRESSION OF THE FREEZING-POINT OF METALS.

In 1889, Prof. Ramsey determined the molecular weight of many metals by the method of measuring the change of vapor-pressure of the solvent, mercury, at various temperatures below and at its boiling point. From these experiments he states, "that it would appear legitimate to infer that in solution, as a rule, the atom of a metal is identical with its molecule, as the physical properties of those metals which have been vaporized would lead us to suppose."

Messrs. Heycock and Neville found that when two metals were melted together, considering *M* as a solvent and *N* as the metal dissolved, then,

(1) The freezing-point of *M* is lowered—the most usual result.

(2) The freezing-point of *M* is raised, *e.g.*, silver in cadmium and antimony in tin.

(3) The freezing-point is unchanged, *e.g.*, thallium in lead, and I believe, within narrow limits, silver in gold.

These investigators, to whom we are so much indebted for their careful researches upon alloys, went further and showed that none of these cases was at variance with Van't Hoff's theory of solution. They did this by filtering off in each case the part first solidifying. In the first case the more fusible filtrate was found to be richer in dissolved metal than were the crystals. In the second instance the opposite was true, for the crystals were richer in dissolved substance, *N*; *i.e.*, the solvent was not first to crystallize, but what was probably a definite compound having a

melting-point higher than its constituents. The pure metal *M*, and the compound $M_xN_y$, then, form isomorphous mixtures, whose melting-points are all above that of *M*.

In the third case there was absolutely no separation of the two metals during cooling; *i.e.*, the first crystals and the fluid part were identical. The two metals, in such a case, form isomorphous mixtures.

In these experiments of Messrs. Heycock and Neville, only very dilute solutions were studied, in which, as in the case of dilute salt solutions, it might be expected that the molecules of the dissolved substance would obey the laws of gases. From these experiments it would seem likely that solid alloys exhibit osmotic pressure, and that there is an expansive tendency upon the part of the dissolved substance to escape from the solution.

When these experiments were performed quantitatively, Heycock and Neville found that two of the empirical laws of Coppet and Raoult hold good for alloys, viz.:

(1) For moderate concentration the fall of the freezing-point is proportional to the weight of dissolved substance present in a constant weight of solvent, and,

(2) When the falls produced in the same solvent by different metals are compared, it is found that a molecular weight of a dissolved metal produces the same fall whatever the metal is.

In these experiments tin was the solvent, and it was assumed that the metals are monatomic, or that their molecules are all of one type, $R_n$, when $n$ is constant and probably $= 1$.

The third law is probably incorrect, for it assumes that if a constant number of molecules of solvent be employed, the fall is independent of the nature of the solvent. The solvent in the case of metals often tends to chemical combination with the other metal. Thus gold in 100 atoms of sodium gave 4° fall; in tin, 3°; and in potassium, only 1·8°.

## FREEZING-POINT CURVES.

Having now made plain, I hope, the nature and meaning of the cooling curves of a metal or alloy, we next direct

attention to freezing-point curves. These are constructed by plotting the critical points of a large number of cooling curves, using as before temperature for the vertical axis, but percentage composition, and not time, for the horizontal co-ordinate; that is, in studying such a series of alloys as the copper-aluminum series, we take the cooling curves of, say, twenty-five alloys varying in composition between Al = 0 per cent. and Cu = 0 per cent. *Fig. 13.* In preparing

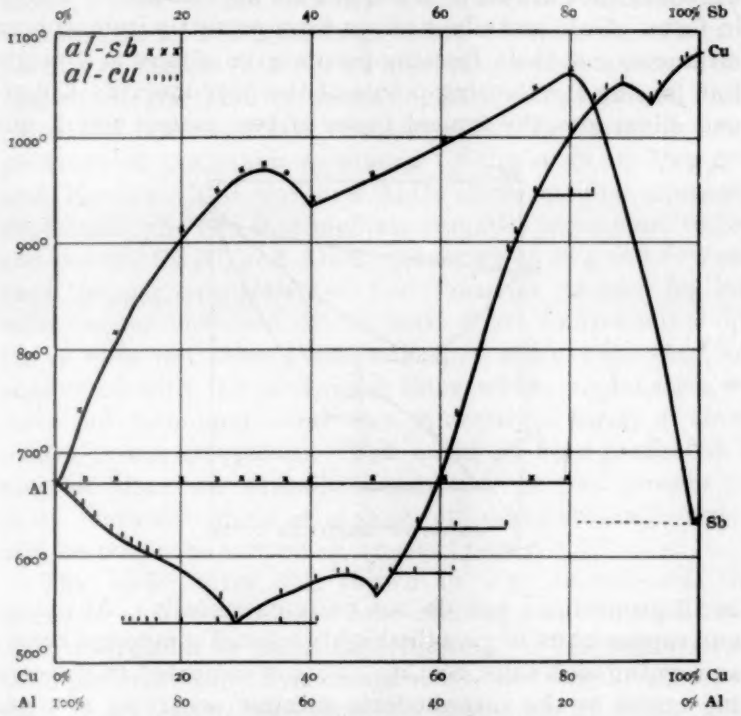


FIG. 13—Cooling curves.

this curve, the cooling curves of alloys corresponding to all the dots along the upper line were obtained. When two or more dots are seen in the same vertical line it indicates that in the cooling curve of the alloy of corresponding composition two or more halts occurred in the movements of the galvanometer. In either end of the curve only one break occurs; the alloys at either end of the series are

solid solutions. Extending from Al, 84 per cent., to Al, 55 per cent., the crystallization of a eutectic is indicated by the line of horizontal breaks. The composition of the eutectic is Al, 67; Cu, 33 per cent. The other horizontal lines are not eutectics; their meaning has not yet been discovered. Before discussing such complicated curves as these, let us consider what are the general types of curves which are obtained with different alloys. In *Fig. 14* the curves are not drawn to scale, but are approximately correct in form. Gold and silver alloys form perfectly isomorphous mixtures, and their freezing-points give almost a straight line joining the freezing-points of the pure metals. Copper and silver give the typical curve of two metals which mix

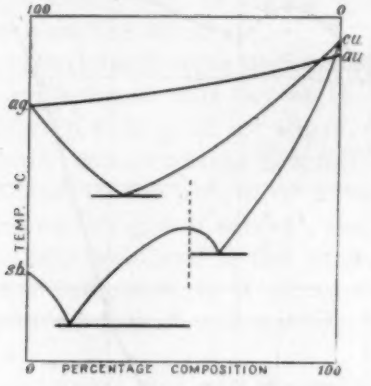


FIG. 14.

in all proportions but do not unite chemically. Antimony and copper unite to give the highly colored compound known as regulus of Venus, $Sb_2Cu_5$. This is indicated in the cooling curve by the intermediate summit occurring at a percentage composition equivalent to $Sb_2Cu_5$. In general such summits will be found to occur at points corresponding to simple atomic proportions, and indicate an intermetallic compound. To explain such a curve we have only to consider it as made up of separate sections as indicated by the dotted line in our figure. The compound has a melting-point of its own, quite independent of that of the constituent metals. It may be higher, lower or intermediate as

compared with the individual metals which enter into its composition. In the Sb-Cu curve we must consider that one series of alloys is composed of Sb and $Sb_2Cu_5$, and the other of $Sb_2Cu_5$ and Cu. We are virtually dealing with two series of alloys, each of which taken separately is of the simple type illustrated by the Ag-Cu curve. In the Sb-$Sb_2Cu_5$ portion of the curve there can be no free copper, and in the Cu-$Sb_2Cu_5$ portion there can be no free antimony. This is not strictly true, because intermetallic compounds, as a rule, undergo some dissociation. In each portion of the curve, then, we are dealing with a pure metal and an intermetallic compound. Each component of these pairs has its respective freezing-point depressed by the presence of the other, as shown by the work of Heycock and Neville. The author's Al-Cu curve may be similarly explained; the two intermediate summits correspond to the compounds $Cu_2Al_5$ and $AlCu_3$, occurring at 48·4 and 87·6 per cent. copper respectively. Le Chatelier thinks he has microscopic evidence of at least four compounds; our curve does not show them, unless, in some way, they are connected with the horizontal lines, whose explanation we have not fathomed. Our own microscopic study of these alloys is not completed. The curve as here presented is simpler than we actually found it to be; we present its main features simply as a type; its complete explanation will be made the subject of another paper.

The Al-Sb curve, also shown in *Fig. 12*, indicates the presence of a compound whose melting-point is more than 400° above that of either constituent. Its formula is SbAl (81.6 per cent. Sb). The components into which this curve may be resolved, then, are Sb-SbAl and SbAl-Al. The compound seems to be almost insoluble in either metal, but on theoretical grounds we should expect to find a slight depression in the freezing-point of each metal by the addition of a small amount of the other to it, but this has not been detected experimentally. In the case of tin-aluminum alloys, however, I detected a fall of 3° in the freeezing-point of tin by the addition of 0.5 per cent. Al, while with increased additions of Al, the freezing-point is raised over 300° at a

concentration of 10 per cent. Al, 90 per cent. Sn. The freezing-point curve of the Au-Al alloys is very complicated, but it presents some original features, and we present it with some words of explanation quoted from Mr. Neville, *Fig. 15*. His remarks bear upon the relation of metallography to freezing-point curves, and also to the possibility of the existence of compounds not indicated by a summit. Excluding the branches *AB* and *IJ*, each of the others *may* represent a compound. The point *E* corresponds to the composition $Au_2Al$. "The microstructure shows that the summit *E* is an almost homogeneous body, and that all solid alloys whose composition lies between that of *D* and

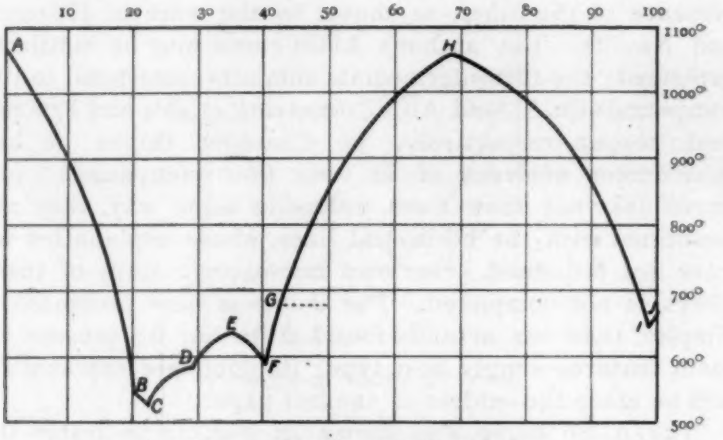


FIG. 15—Atomic percentage of Al.

*F* contain large crystals of the body *E* immersed in a mother-substance. As we descend the curve from the summit, the large crystals of *E* are found to occupy less and less of the whole alloy until at *D* and *F* they cease to exist. Exactly similar phenomena show themselves on the branch *GHI*. The summit *H* occurs at the formula $AuAl_2$. [The beautiful purple alloy of Roberts-Austen.] . . . These criteria taken together—(1) the occurrence of a summit at a formula percentage; (2) the presence of large crystals of the same kind, decreasing in amount as we decrease the branch on either side are, considered by Mr.

Neville, "an absolute proof of the reality of a compound." In the British Association report (1900) from which I quote, Mr. Neville gives arguments to show that such a branch as *FG* may indicate a compound and concludes: "Thus an alloy may contain a compound, although that compound does not occur as the sole constituent of any particular alloy." This point requires further study, it seems to me, and judgment should be withheld until further evidence is produced.

## UPON THE NATURE OF EUTECTICS.

We are indebted to Dr. Guthrie for the name "eutectic," and we shall do well to confine the use of the term to indicate the most fusible alloy of a series—the one which freezes last. Eutectics may differ in certain properties and upon these differences they may admit of classification, but all eutectic alloys possess these common properties:

(1) They are, in any one series of alloys, of uniform composition.

(2) Their freezing-point is constant throughout any one series.

(3) Their freezing-point is the lowest in the series.

(4) They are not chemical compounds.

Their composition may, and occasionally does, correspond to some simple atomic ratio. This coincidence, though striking, does not prove the presence of a compound as the sole constituent of a eutectic. Usually they possess a more or less laminated microstructure. Often it requires the very highest magnification to detect the two constituents. Mr. Stead, in his splendid paper upon "Iron and Phosphorous" (*Jour. Iron and Steel Institute*, 1900) gives some ideas upon the subject of eutectics, and besides recognizing the essential features which we have already mentioned, adds that a eutectic may consist: (1) "Of two or more metals which do not unite chemically; (2) of a metal and a definite compound containing that metal; (3) or possibly of two or more definite compounds. (4) It may consist of a mixture of a solid solution of one metal in another

and a free metal. (5) It may contain a solid solution of a definite metallo-metallic salt and that same metallo-metallic salt in the free state. (6) It may possibly consist of two solid solutions." To my mind the last of these statements is the most general of all, even though Mr. Stead qualifies it with the word "possibly." It embraces several of the preceding conditions, and since I am unwilling to admit that any metal or intermetallic compound ever separates *absolutely* pure, those conditions in which Mr. Stead speaks

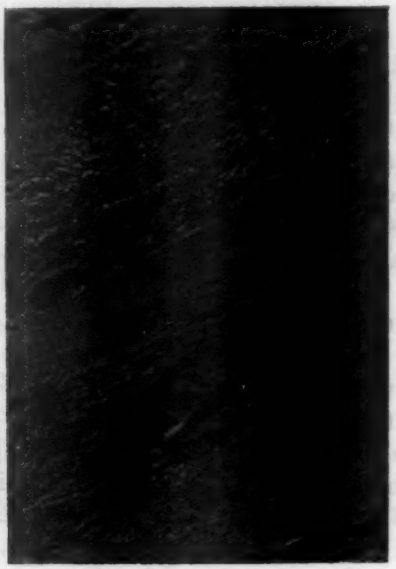

FIG. 16.

of the separation of pure substances seem to me slightly inaccurate. The most that we can say of them is that they are solid solutions of very small concentration. The form of freezing-point curves showing eutectics, together with Professor Roozeboom's explanation of them, renders it improbable that any strictly pure material separates at the point at which the eutectic solidifies. This does not in any way concern the phenomenon of a eutectic, or one of its constituents, splitting up at still lower temperatures into

its elemental constituents, *e. g.*, iron carbide, *may* split up into *pure* iron and *pure* carbon.

In some alloys whose freezing-curve lies almost wholly above the melting-point of either or both constituents, but in which there is a slight depression of the freezing-point at either end for small additions of one metal to the other, as in the Sb-Al or Sn-Al series, and where this depression is further indicated in a well-marked eutectic break in the cooling-curves of the various alloys of the series examined,

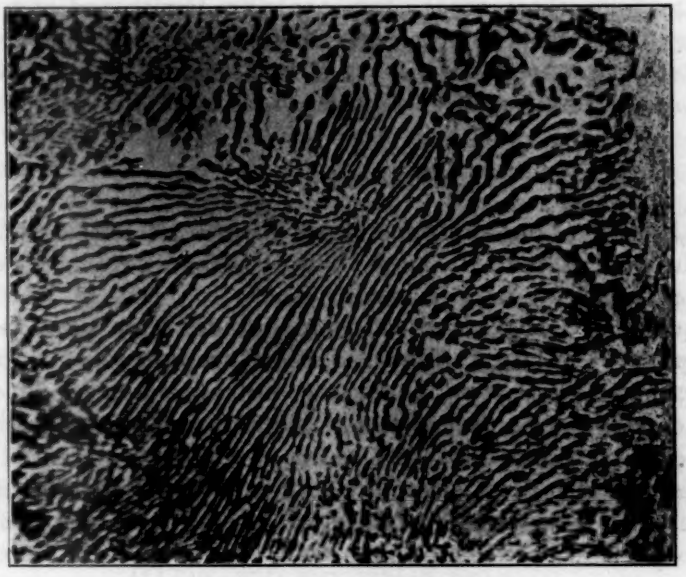

FIG. 17.

it may be possible that the eutectic is a single solid solution. The quantity of dissolved substances in such cases might not be sufficient to seriously change the type of cooling-curve, and probably the highest magnification would not resolve such a eutectic into two components. The fact that it crystallizes isomorphously with the pure metal argues that no two juxtaposited constituents are there. While our own work is not conclusive on this point, we may add that this conception of an eutectic is in no way

opposed to the four essentials stated above, or with Dr. Guthrie's definition. The fact that in certain cases, *e. g.*, the 1 per cent. Cu, 99 per cent. Sn alloy, we may have a well-marked characteristically banded structure (*Fig. 16*) argues for rather than against the idea that a single solid solution may be a eutectic; for the absence of this structure in some dilute metallic solutions, and the isomorphism of the ground mass in such cases with pure metal seems to strongly confirm this idea. The typical metallographic structure of eutectics is illustrated by *Figs. 16* and *17*. The latter is pearlite, whose components are ferrite and cementite. This banded structure, however, need not be considered as essential. *Fig. 17* is by Osmond and is taken from Roberts-Austen's "Introduction to Metallurgy."

## SOLID SOLUTIONS.

In all that has preceded alloys have been considered as solutions of metals; many points of similarity between alloys and ordinary solutions, (such as gases in liquids, liquids in liquides and solids in liquids) have been mentioned. The latter class of solutions are fully discussed in text-books on physical chemistry, but the extension of our knowledge upon the subject of solutions of solids in solids is of very recent date and, so far as we have advanced in this field of investigation, the results are mostly confined to technical periodical literature of recent date. Professsor Roozeboom and his pupils have conducted very careful researches upon the nature of fused mixtures of metallic salts and their behavior upon cooling (see Roozeboom, Stoffe and Van Eyk; and Reinders, and Hissink—*Zeits. Phys. Chemie.* Vols. xxx and xxxiii, respectively). This work throws considerable light upon the problems of chemical equilibrium in alloys.

Prof. Sir William Roberts-Austen defines a solid solution as "a homogeneous mixture of two or more substances in a solid state. In metals, no one has worked as yet with non-crystalline mixtures and solid solutions of metals when crystalline are solid 'isomorphous mixture' or 'mixed

crystals.'" Mr. Stead, from whose paper we quote this definition, classifies solid solutions as follows:

(1) "Those in which one constituent of an alloy in crystallizing retains a portion of the other homogeneously diffused through its whole crystalline mass."

(2) "Those in which during crystallization the central portion of the crystals contains less of the dissolved metal than their external boundaries." (The condition described here corresponds to that of an unstable system. Complete homogeneity could probably be obtained by long annealing.)

(3) "Those in which the metals form a definite compound which is retained in solid solution in the excess of metals." (I should like to add that the "compound" may be the "solvent" in the sense in which that term is here used, and retain one or other of its constituent metals in solid solution. This accounts for the fact that when crystals of an intermetallic compound are isolated and analyzed, their compositions vary when the crystals have been isolated from alloys of different compositions.)

(4) Mr. Stead adds, "those in which the nonmetallic elements form definite compounds with a proportion of the dissolving metal that remain in solid solution." While probably referring to the phosphide and carbide of iron primarily, Mr. Stead's fourth class would include the property of such metals as copper and iron to dissolve a quantity of their respective oxides. Such solutions have not been studied in the light of modern theories.

## ALLOYS AND THE PHASE RULE.

The phase rule of Gibbs, which has been found to be of inestimable value in explaining chemical equilibrium in liquid solutions, is of equal applicability to such complex solids as alloys. There may be, however, some difficulty in applying the sound theoretical principles upon which this doctrine is based, because of the fact that, owing to too rapid cooling, equilibrium may not have been attained in the particular alloy which we are studying. This seems only natural when we reflect that perfect equilibrium in a liquid solution is only attained slowly, and we cannot

expect in a solidifying mass to find complete equilibrium when the molecular freedom is so much less than in ordinary solutions. The rate of cooling in some cases would have to be extremely slow to insure complete equilibrium and therefore one need not be surprised to find that his microscopic and pyrometric results do not agree with the theoretical constitution demanded by the provisions of the law of phases. If, however, equilibrium has been established then the number of distinct substances in the mass will depend upon the number of constituents which enter into the composition of the mass. Let us recall Professor Trevor's classification of systems as provided for by the phase rule, and later we shall point out how this must be modified when applied to alloys.

(1) When in any system the number of phases exceeds the number of components by two, the system is nonvariant.

(2) When the number of phases exceeds by one the number of components the system is monovariant.

(3) When the number of phases is equal to the number of components the system is divariant.

To understand these statements we must first know what is the strict meaning of the terms, "phase" and "component" as here used. As defined by Professor Bancroft, "A phase is a mass chemically or physically homogeneous, or a mass of uniform concentration; the number of phases in a system is therefore the number of different homogeneous masses, or the number of masses of different concentration." According to the same authority, "The components of a phase or system may be defined as the substances of independently variable concentration in the phase or system under consideration."

If we are going to consider alloys, both liquid and solid, as solutions—and the tendency of present methods of research seems to favor this conception of them—then it will obviously facilitate matters if we adhere as closely as possible to the phraseology, definitions and general usage of terms as employed by the best authorities upon this subject. This fact has been lost sight of by some writers and considerable confusion has arisen. For example, it does

not seem to me that the adaptation of the phase rule which Le Chatelier gives (*Comptes Rendus*, January, 1900, and the *Metallographist*, October, 1900) is at first sight at all comparable with Trevor's classification of systems, which is the one with which all English speaking chemists become familiar in their studies of chemical equilibrium. Professor Le Chatelier's formula is correct, but how or why does not appear, nor does his explanation accompanying the formula make clear that any relationship exists between Trevor's generally accepted classification as applied to solutions and his own formula as applied to rocks, alloys, etc. That is, one misses the point entirely that not only do alloys resemble solutions, but *are* solutions; the very fact of the applicability of the phase law to them is strong evidence to that effect.

Let us see what Trevor's classification of systems means. Suppose $n$ equals the number of components, and $r$ the number of phases. Then these three generalizations become

(1) $n + 2 = r$, a nonvariant system.
(2) $n + 1 = r$, a monovariant system.
(3) $n = r$, a divariant system.

Then, in the case of single substances, such as water, $n = 1$, whence in equation (1), $r = 3$,—the maximum number of phases of a single substance which can exist in equilibrium, but only at one temperature and pressure, for the system is nonvariant. Concentration is obviously not a variable in the case of a single substance. If, in such a system as the above, either temperature or pressure varies, one of the phases will disappear. If a system of one component exists in but two phases, it has one degree of freedom, *i. e.*, it is monovariant. In other words, for each pressure there is one temperature, and for each temperature there is one pressure at which the two phases are in equilibrium. A single substance in a single phase constitutes a divariant system, for within certain limits temperature and pressure can vary independently.

When two substances (components) are present, as salt and water, then $n$ being 2, $r$ is 4. That is, a system of two

components may exist in four phases in equilibrium, but only at one temperature, one pressure and one concentration. But in a system of two components and three phases (monovariant) wher one condition is fixed, either temperature, pressure or concentration, the other two adapt themselves to suitable values and equilibrium is maintained and no phase disappears. The fixing of one of the physical conditions thus defines the system. When the number of phases and components are equal, then fixing one condition no longer defines the system, for the other two conditions are capable of variation; *i.e.*, if temperature is fixed, changes of pressure will give rise to a series of concentrations, or, by changing the concentrations we get a series of pressures; similarly, if the concentration is fixed, then equilibrium is maintained if all changes in pressure are attended by concomitantly opposite changes in temperature.

These are the general principles regarding the application of the law of phases to systems in equilibrium containing either one or two components, when pressure, temperature, and, in the latter case, concentration are the variable conditions. When we apply this law to the explanation of problems of equilibrium in alloys some modification of the numerical expressions defining the systems is necessary. This modification is in the nature of simplification, for with metals and alloys under usual working conditions the pressure is approximately one atmosphere and the vapor pressure is so small that its variations with slight changes in barometric readings from time to time are absolutely inappreciable. Therefore we may properly disregard pressure as a variable and vapor as a phase affecting equilibrium. Consequently, with pure metals we have but one variable physical action, temperature, while in alloys the variables are temperature and concentration. Since the number of possible phases is diminished by one (vapor being neglected) our equations become,

(1) $n + 1 = r$, a nonvariant system.

(2) $n = r$, a monovariant system.

(3) $n - 1 = r$, a divariant system.

In a system of one component, *e. g.*, a pure metal, $n = 1$ and the first equation gives $r = 2$, *i. e.*, metals may exist in two phases in equilibrium, but only at a single temperature, for the system is nonvariant. If heat is added, solid metal becomes liquid; if heat is abstracted liquid becomes solid; or the change may be from one allotropic form to another at a fixed temperature; the equation does not give the number of possible phases, but simply how many of them may be simultaneously existing in equilibrium.

In the second equation, $r = 1$, *i. e.*, within certain limits in a system of one component and one phase the temperature is independently variable. Equation three gives $r = 0$, which is impossible, *i. e.*, one component cannot constitute a divariant system when there is but one variable physical action under consideration.

Passing now to binary alloys, we have two physical variables: temperature and concentration; in our equations, since $n = 2$,

(1) gives $r = 3$, a nonvariant system.

(2) gives $r = 2$, a divariant system.

(3) gives $r = 1$, a divariant system.

In other words, when there are two variables:

two components and three phases = nonvariant system,

two components and two phases = monovariant system and

two components and one phase = divariant system.

In regard to determining the number of components in a system, Professor Bancroft says that the main point to be observed is, that each compound is not necessarily a component, and the fact that two components unite to form a phase in definite proportions does not entitle us to call this resulting compound or combination a component if we are dealing with the equilibrium of this resulting compound with the constituents which go to compose it. Thus, according to Professor Bancroft, in dealing with the equilibrium of $CaCo_3$, with $CO_2$ and $CaO$, we have but two components, and the $CaCO_3$ is simply a solid phase containing them, and, he continues: "On the other hand, it is not permissible to

take calcium and oxygen as two of the actual components of this system, because they are neither independently variable, nor are they in equilibrium with the system." The accompanying table shows the relationship between the expressions applicable to liquids and solutions on the one hand and metals and alloys on the other, in a form which admits of easy comparison. From this it will be noticed that the expressions indicating the different systems are the same, whether $n$ equals 1 or 2, but differ when the number of physical actions vary. In this table $n$ = components; $p$ = physical actions or variables, and $r$ = phases.

TABLE OF COMPARISON.

| | | | |
|---|---|---|---|
| $n$ | Single liquid, *e. g.*, $H_2O$. $= 1$. | Single metal, *e. g.*, Au. $= 1$. | $n$ |
| $p$ | Temperature, pressure. | Temperature. | $p$ |
| $r$ | Vapor, liquid, solid (ice). | Liquid, solid. | $r$ |
| Then (1) | $n + 2 = r_1$ = nonvariant system; *i. e.*, $r = 3$, gives " " | $n + 1 = r_1$ = nonvariant system; *i. e.*, $r = 2$, gives " " | (1) |
| If $r$ then (2) | = vapor and liquid, $n + 1 = r_1$ = monovariant system; *i. e.*, $r = 2$, gives " " | Liquid *or* solid, $n = r_1$ = monovariant system; *i. e.*, $r = 1$, gives " " | $r$ (2) |
| If $r$ then (3) | = vapor, $n = r_1$ = divariant system; *i. e.*, $r = 1$, gives " " | There can be no divariant system, for, $n - 1 = r$ in this case gives $r = 0$. | $r$ |
| $n$ | Liquid solution, *e. g.*, $H_2O$ and NaCl. $= 2$ — water and salt. | Binary alloy, *e. g.*, cast-iron. $= 2$ iron and carbon. | $n$ |
| $p$ | Temp'ature, concentrat'n, pressure. | Temperature, concentration. | $p$ |
| $r$ | Salt, ice, vapor, saturated solution. | Liquid cast-iron, solid solution of carbon in iron, graphite. | $r$ |
| Then (1) | $n + 2 = r_1$ = nonvariant system; *i. e.*, $r = 4$, gives " " | $n + 1 = r_1$ = nonvariant system; *i. e.*, $r = 3$, gives " " | (1) |
| If $r$ then (2) | = salt, solution, vapor, $n + 1 = r_1$ = monovariant system; *i. e.*, $r = 3$, gives " " | Liquid cast-iron, graphite. $n = r$, monovariant system; *i. e.*, $r = 2$, gives " " | (2) |
| If $r$ then (3) | Salt and solution, $n = r_1$ = divariant system; *i. e.*, $r = 2$, gives " " | Liquid cast-iron (*i. e.*, carbon solution in iron). $n - 1 = r_1$ = divariant system; *i. e.*, $r = 1$, gives " " | (3) |

There remain two points in regard to the application of the phase rule to alloys that may be touched upon briefly. First, the equations given do not indicate the number of phases in which one or two components may exist, but the number of phases that can exist simultaneously in

equilibrium. Pure iron may probably exist in three solid and one liquid phase, but never in all at a single temperature. According to Roozeboom the iron-carbon alloys, while consisting of but two components, may exhibit at least seven phases, viz.: carbon, gamma-, beta- and alpha-iron, liquid solution, solid solution of carbon in gamma-iron or martensite, and cementite or iron carbide, $FeC_3$. Second, in applying the phase rule to pure intermetallic compounds we must consider that we are dealing with a system of one component. The composition of its phases, whether liquid or solid, is fixed by the law of definite combining proportions. When existing alone, therefore, it obviously can exist but in a liquid and solid phase giving a nonvariant system, or in the liquid *or* solid phase as a monvariant system—the temperature within limits being independently variable; concentration is not a factor any more than with a pure metal.

Let us now explain the freezing-point curve of a typical series of alloys considered as an equilibrium curve and in the light of the phase rule. *Fig. 18* shows the freezing-curve of the Cu-Ag series. The curve *a*, *e*, *c*, represents the temperatures at which solidification begins to take place for any given concentration. The curve *a*, *b*, *d*, *c* shows the temperature at which solidification is complete. Except for the eutectic portion of this curve the exact position of it is not known; *i. e.*, in our figure the dotted portions are conjectural. They may be calculated with some degree of accuracy, according to Stansfield, when the latent heat of fusion of the solvent is known and assuming that the dissolved substance is monatomic in the liquid state. The upper line *a*, *e*, *c* is what Roozeboom calls the "liquid" curve; the lower lines, *a*, *b*, *e*, *d*, *c* he calls the "solid" curve. When the liquid and solid curve have a maximum or minimum point, as in the curve before us, they touch, and the liquid whose composition corresponds to this point of meeting will solidify at a single temperature. A similar diagram to this one may be used in explaining such complicated curves as the Al-Cu curve if we remember that the terminii of the liquid and solid curve need not be pure

metals, but may be a metal and a compound, or perhaps two compounds. The more or less triangular areas, *a*, *b*, *e* and *c*, *d*, *e* represent mixtures of liquid and solid phases. The areas *a*, *b*, *r*, *f* and *c*, *b*, *d*, *s* are solid solutions and *b*, *d*, *f*, *g* is the area of solid eutectic. Above the liquid curve we have only liquid phases, while below the solid curve we have only solid phases, and, as has been said, intermediate areas correspond to a mixture of liquid and solid phases.

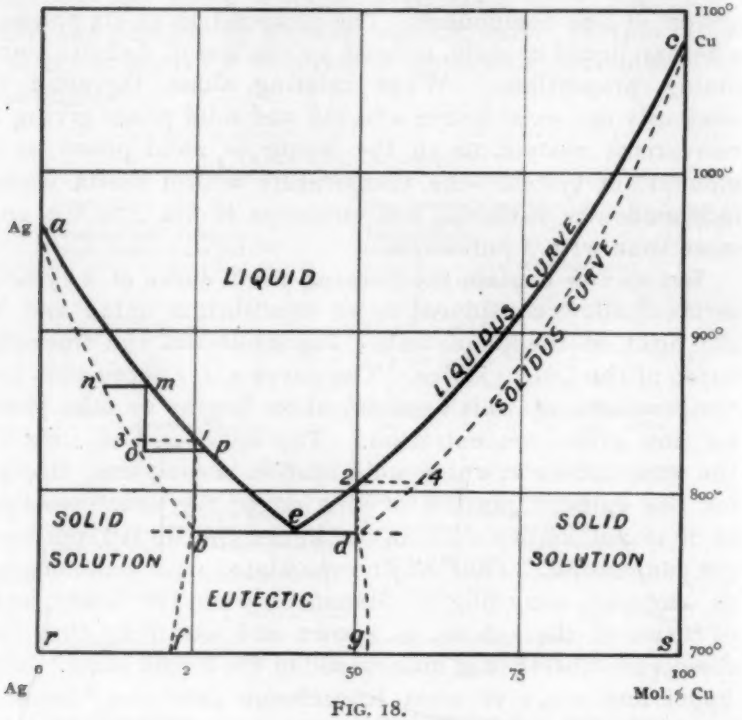


FIG. 18.

Let us consider the phenomena exhibited during the cooling of alloys represented by compositions along the branch of the curve *a*, *e*. Identical phenomena are displayed by alloys on the other branch *e*, *c* of the freezing-curve. At the points *a* and *e* we are dealing with pure silver and eutectic respectively; since both the freezing-point and the composition of these is fixed, we have at *a* and *e* nonvariant systems.

All points in the liquid area correspond to a system of two components, Cu and Ag; and one phase, solution; hence divariant. Within the area marked "solid solution" we also have a divariant system; the components are the same—the phase is solid solution. The temperature and concentration of either the liquid or solid solution are free to vary so long as no curve in the diagram is intersected. In the case of the eutectic, since composition is fixed, we have a monovariant system: two components and two phases, viz., solid solution of copper in silver and solid solution of silver in copper. The temperature may vary independently until it rises to the melting-point of the eutectic. The area marked "solid eutectic" is apt to be misleading. Any point in it represents an alloy whose composition is of the average composition indicated by that point when projected upon the composition line, but alloys in this area are not composed of pure eutectic only, as the figure seems to indicate, but of eutectic plus solid solution. The eutectic itself is composed of two solid solutions whose compositions are indicated at the points where a horizontal line through the point in question cuts the lines *b*, *f* and *d*, *g*. These lines indicate the maximum solubility of either metal in the other, and since this probably decreases, even after solidification, they are properly drawn somewhat slanting. The meaning of this area, therefore, is that such alloys as give a eutectic point in their cooling curve consist of a conglomerate of solid phases, while all solid alloys lying outside of this area are homogeneous and consist of but one phase.

According to Professor Roozeboom the phenomenon of solidification takes place in this way. Any alloy represented, *e. g.*, by a composition which we will call *m*, begins to solidify by the separation of crystals of the composition *n*. They therefore contain less copper than liquid alloy *m*. The residual liquid has therefore become enriched in copper and its freezing-point is lowered, and its composition passes from *m* to *p*, at which point final solidification takes place, giving crystals of the composition *o*; that is, while the liquid solution is changing from *m* to *p*, the composition

of the mixed crystals has changed from *m* to *o*. Complete solidification has thus taken place through an interval *m*, *o*. There is an alloy, obviously, whose final solidifying point is *b*; at this point it is a liquid of composition *e* which solidifies. Similar changes take place on the branch *c*, *e*, so that all alloys between compositions *1* and *2*, after separating out crystals of solid solution of Cu in Ag or Ag in Cu, whose compositions vary respectively along the lines *3*, *1* and *2*, *4*, become concentrated to the composition *e* where saturated solid solutions represented by the compositions *b* and *d* solidify side by side, constituting the eutectic; that is, any alloy the vertical projection of whose composition upon the solid curve does not intersect the eutectic line consists of a single solid solution. Any alloy whose composition projected vertically intersects the eutectic line consists, when solid, of a conglomerate of eutectic of constant composition *e* (made up of two solid solutions of compositions *b* and *d*) and a solid solution whose composition is represented by the horizontal projection of its composition upon the corresponding solid curve.

At points in *a*, *b*, *e* and *c*, *e*, *d* solid solutions and liquid solutions are in equilibrium; *e.g.*, at the temperature *mn* there exists in equilibrium solid solution of composition *n* and liquid solution *m*. The relative amounts of these depend upon the concentration of the original alloy. Along the line *b*, *d* liquid solution of composition *e* and solid solutions of the compositions *b* and *d* are in equilibrium. The system is nonvariant. At points along the curves *a*, *e* and *a*, *b* monovariant systems exist, the phases in each being liquid and solid solution. By definition eutectic is the last substance to freeze; therefore, solid eutectic can only be in equilibrium with a liquid solution of its own composition *e*, and with solid solution. All points on *b*, *e*, *d* represent nonvariant systems, for here two components may exist in three phases at the temperature represented by the line of the eutectic.

In discussing the application of the law of phases, LeChatelier says that in a mixture of solid bodies at ordinary temperatures, and resulting from such reversible transformations as solidification through cooling or crystal-

lization from solution, it appears that the stable state corresponds to a monovariant system; *i. e.*, the number of phases must be equal to the number of independent constituents (components) which enter into its composition, The result of this applied to alloys obtained by fusion is, that when a nonvariant system is cooled below its point of last solidification, one of these phases disappears. The system becomes monovariant and remains so to the ordinary temperature, provided none of the solid substances undergo any subsequent transformation during cooling. Otherwise it passes through a new invariant point, as in the case of carburretted iron, and always reaches a monovariant system, As indicating the direction of change in equilibrium when the system is altered, Le Chatelier says: "Any change in the factors of equilibrium from outside is followed by a reverse change within the system." "Thus," according to Professor Bancroft, "if heat is added there is an increase in the formation of the component or phase involving an absorption of heat. In other words, the system in equilibrium tends to return to equilibrium by elimination of the disturbing element." To illustrate, we might mention slowly cooled cast-iron. It usually consists of two components—iron and carbon; and three phases—iron, graphite and carbide. The system is nonvariant. It is unstable in the solid condition and on re-heating the carbide of iron phase disappears, breaking up into iron and graphite. There are now two phases and two components—the system is monovariant and, according to Le Chatelier's theorem, is stable.

## CONCLUSION.

It may seem to you that in what has gone before I have laid too much stress upon pyrometric methods and the curves which they afford. I have done so purposely, as I considered this the least familiar to Americans of all the methods of studying alloys. I would not presume, either, to go into details of the value of metallography, since I see that such an eminent authority as Mr. Sauveur is to follow me in this course of lectures, and other gentlemen are to present papers to you upon metallographic topics. Again, I have made no mention of the value of electrical conduc-

tivity, tensile strength, elasticity and other usual physical and mechanical tests. They are of the utmost practical value, but they may be safely omitted from *one* lecture, for, to tell the truth, they have been too long relied upon to give all the information necessary in regard to alloys. I think it will not be long before both metallography and scientific pyrometry will be considered indispensable in metal work, the latter not only to give evidence in regard to freezing-points and equilibrium curves, but to regulate to a nicety the temperature of annealing, tempering and working processes. In regard to the recent contributions to our knowledge of alloys, I regret to say that too much of it has come from foreign sources. As a nation we have not done our part in this branch of investigation. You may recall that almost without exception the authorities I have quoted have been English or French scientists. Mr. Sauveur is compelled to seek most of the material for his valuable journal, *The Metallographist*, from these same authorities. How long is this to continue? When are American scientists to assume their just share of this work? When will our technical societies give it official recognition as the Institution of Mechanical Engineers and the Société d'Encouragement pour l'Industrie Nationale have done? It will be universally admitted that there are yet many problems in regard to alloys awaiting solution. To solve these problems is to open the way for great industrial advances in every industry that is dependent upon metals and alloys in any way, and what manufacturing industry is not? Research is the one means of bringing about their solution. Pardon me, in conclusion, for making a new and figurative adaptation of the law of phases to this kind of "solution." We are dealing with a system of one component—research; time and toil are the physical actions; metallography, pyrometry and physical-mechanical testing of the ordinary sort are the phases. The phases exceed the components by two; the system is nonvariant. Let us not be discouraged because of the magnitude of the numerical equivalent of the physical conditions. Our knowledge in no department of science is complete.

[*To be concluded.*]

# IN MEMORIAM.

## JOHN G. BAKER.

John G. Baker, an active and highly esteemed member of the Franklin Institute, died on Sunday, December 8, 1901, after a lingering illness.

JOHN G. BAKER.

Mr. Baker was born near Princeton, N. J., on May 11, 1833. He served his apprenticeship as a carpenter, and shortly thereafter established himself in business in the city of Washington as a model-maker for inventors.

His subsequent career as an inventor of many ingenious implements and machines made him widely known and brought him reputation and a competence.

His first invention was a machine for making glaziers' points, which he later modified into a machine for toothing hand-saws. This invention was adopted by Henry Disston, the Philadelphia saw manufacturer, in whose employ Mr. Baker entered in 1861. While in the Disston works Mr. Baker invented and successfully introduced a number of devices for grinding various kinds of saws and other labor-saving devices.

In 1864 he associated himself with T. Henry Asbury, under the firm name of Asbury & Co., for the manufacture of an indicator to save the reverse belt in screw-cutting lathes.

The firm of Asbury & Co. was dissolved and the Enterprise Manufacturing Company was organized in 1866. In

the development of this company's operations Mr. Baker's ingenuity as an inventor proved conspicuously fruitful. No less than forty inventions originated with him in connection with the company's business, many of which have become staple articles in the hardware trade. The most useful of these, perhaps, are a meat-chopper and a self-measuring faucet for drawing and measuring molasses and other heavy liquids, both of which are extensively used throughout the United States.

His most important invention was the well-known "Baker pressure blower," now largely in use in foundries and mines, and for which he was awarded the John Scott Legacy Premium and Medal by the Board of City Trusts of Philadelphia, on the recommendation of the Franklin Institute, in January, 1875.

He retired from active business in 1888, though he continued to retain the position of Vice-President of the Enterprise Manufacturing Company until his death.

Mr. Baker was the typical American mechanic—resourceful, self-reliant, and ingenious—and possessed of the rare faculty of quickly perceiving and applying the simplest, most direct and effective methods of solving a mechanical problem presented to him. Even after his retirement from active business, to enjoy the evening of his useful life in leisure, he still took delight in inventing devices of various kinds. An ingenious stereoscopic camera and improvements in fishing-tackle were the fruits of these leisure hours.

Mr. Baker became a member of the Franklin Institute in 1866, and from his earliest connection with the society manifested a lively interest in its work. His services were always at command for committee work, as the records of the Committee on Science and the Arts bear testimony. His reluctance to figure conspicuously among his associates caused him repeatedly to decline election to the directorship, a position which he was frequently urged to accept. On more than one occasion he contributed substantially to the financial needs of the Institute, but these contributions were invariably coupled with the stipulation that his name should not be made known. His lamented death leaves the writer

free to publish that which, in life, his modesty caused him to conceal.

His many sterling traits of character earned for him the sincere respect and esteem of his associates in the Institute.

Mr. Baker is survived by a widow and a married daughter.

W. H. W.

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## PROTECTIVE COATINGS FOR THE IMMERSED PORTIONS OF IRON VESSELS.

The advent of iron ships has been accompanied with a difficulty which has not yet been met satisfactorily, namely, that of a suitable protective coating of the immersed parts to protect them from corrosion and the attachment of marine plants and animals. The latter is the most troublesome, and especially in tropical waters the rapid accumulation of marine growths of this nature in the course of a few months fouls the bottom of iron ships to such an extent that the speed is reduced to one-half or even more. This, of course, materially reduces the efficiency of a vessel—especially of a naval vessel—and necessitates frequent docking for scraping and cleansing.

The old plan generally employed with wooden vessels was to sheath them with copper sheathing. In the case of iron vessels, however, this cannot be done without first applying wooden sheathing to which the copper can be attached, and this is a somewhat expensive operation, which, on this account, is only occasionally resorted to. Nevertheless, unless some efficient substitute for copper sheathing is devised in the near future, this expensive method will have to be adopted.

Attempts have been made to coat the iron hulls of ships with copper electrically by a process of electric plating on a huge scale, but those appear to be unsuccessful. Meantime recourse has been had to the application of various paints and similar protective coatings, none of which, thus far, have proved entirely satisfactory.

The *Chemiker Zeitung* has an instructive article on this subject, from which the following information is derived: The author enumerates the following indispensable conditions for a protective coating for iron ships to realize the requirements of service: (1) The compositions should protect the ship's hull from corrosion; (2) they should form a smooth surface, so as to decrease the friction; and (3) they should dry quickly so that the cleansing of the submarine parts and the application of a double coating can be done in a single day. In the case of new steel vessels, the black scale with plates must first be removed by the use of acid pickle before applying the coating, which otherwise will drop away with the scale and expose the exposed metal to rusting.

The author describes several paint compositions that have been used for this purpose, and gives the preference to that proposed by Rahtjen. This process consists in employing as the vehicle a solution of shellac in spirit, to which is added some iron oxide and a small proportion of linseed oil to give it elasticity. This first or priming coat is intended to serve for insulating the iron hull, and is followed by a second one composed of the same materials

with the addition of arsenic and quicksilver. The Rahtjen compositions are highly commended for their permancy, as the salt of the sea water has but little action on the shellac which constitutes the vehicle of the paints. The efficiency of the second coating as a preventive of marine growths is ascribed to the formation of mercuric chloride by the slow action of the seawater on the quicksilver contained in the composition, and which acts as a poison towards the marine organisms. These paints have the further advantage that they dry quickly, so that several coats may be laid on in a single day.

The defects of the Rahtjen paints are, that only a small quantity of mercury can be incorporated in the paint, as otherwise the shellac would be affected, and that the effectiveness of the paint decreases with time because of the slight solubility of the shellac.

Of the mineral poisons incorporated in these compositions, copper and mercury have been found most efficacious. Copper would be preferable on account of the cheapness, but has the objection that when the insulating or priming coat has become defective, its presence in considerable quantities in proximity to the iron hull is apt to cause rapid corrosion of the iron by galvanic action.

The author of the article above referred to gives also some instructive information as to the manner in which the efficiency of such protective compositions is called into action. Thus he explains: the purpose of the poisons in the paint is to kill the germs of the crustaceous animals, which only swim about freely during the first stages of their development, and in seeking a permanent place of growth, attach themselves to the vessel's hull. While the ship is moving through the water the paint layer is being continually affected by friction, so that the seawater can enter into chemical action with the poisons of the paint, whereby there results the production of an antiseptic (germicide) compound on the surface that destroys the organisms which come in contact with it, and so long as the ship's motion is continued, fresh portions of the paint-film are successively exposed with the same result. In time the antiseptic action of the paint-film ceases by the exhaustion of the poisonous material, when its virtue as a preventive of marine growths ceases, though the insulating coating may still protect the hull from corrosion.

Again, when the hull of the vessel is at rest, as when in harbor, the continuous formation on the surface of the paint layer of an antiseptic substance is arrested, being rapidly exhausted by the vast amount of animal life coming in contact with it, and not being renewed by frictional contact with the water as when the ship is in motion. This is the explanation of the fact that a vessel in port (particularly in tropical waters) fouls much more rapidly than when at sea. It is observed, however, that the antiseptic agents which have thus become exhausted after a few weeks' detention of the vessel in port, again become effective after putting to sea, when the exhausted particles of the paint skin are removed by friction, exposing a new poison-saturated surface.

The whole subject of the proper protection of the hulls of iron vessels from rusting and marine growths is in a sort of transition stage, very much like that of finding an efficient substitute for wood on warships, for, notwithstanding the many remedial agents that have been proposed, none of them has fully met all the requirements, and the problem still awaits its solution.

W.

# Franklin Institute.

[*Proceedings of the annual meeting held Wednesday, January 15, 1902.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 15, 1902.

Vice-President THEO. D. RAND in the chair.

Present, 137 members and visitors.

The annual reports of the Board of Managers and of the various committees and Sections were presented in printed form, and were duly accepted.

The tellers of the annual election reported the election of the following candidates:

| | | |
|---|---|---|
| *For President* | (to serve one year) . . . . . | JOHN BIRKINBINE. |
| " *Vice-President* | ( " three years) . . . . . | WASHINGTON JONES. |
| " *Secretary* | ( " one year) . . . . . | WM. H. WAHL. |
| " *Treasurer* | ( " " ) . . . . . | SAMUEL SARTAIN. |
| " *Auditor* | ( " three years) . . . . | WM. H. GREENE. |

For *Managers* (to serve three years).

| | |
|---|---|
| BENJ. SMITH LYMAN, | THOS. P. CONRAD, |
| COLEMAN SELLERS, | JAMES M. DODGE, |
| ISAAC NORRIS, JR., | C. LELAND HARRISON, |
| STACY REEVES, | FRANCIS SCHUMANN. |

For *Members of the Committee on Science and the Arts* (to serve three years).

| | | |
|---|---|---|
| HUGO BILGRAM, | LEWIS M. HAUPT, | C. J. REED, |
| FRANK P. BROWN, | FRED. E. IVES, | E. ALEX. SCOTT, |
| J. J. DE KINDER, | A. E. KENNELLY, | COLEMAN SELLERS, |
| W. C. L. EGLIN, | WILFRED LEWIS, | H. W. SPANGLER, |
| A. M. GREENE, JR., | EDGAR MARBURG, | MARTIN I. WILBERT. |

Capt. B. W. Dunn, Ordnance Department U. S. A., Frankford Arsenal, presented a detailed description of the Gathmann Gun Tests, illustrating the same by a series of lantern slides showing the results of comparative tests of the Gathmann gun and projectile and the standard service gun and projectile with time fuse, at the Government proving grounds.

Mr. J. O. Nixon, Link-Belt Engineering Company, gave a description of the Renold Silent Chain-Gear, with illustrations, showing the successful application of the gear to a number of diverse machines where in many cases the use of ordinary systems of power transmission would be extremely difficult. The subject was referred to the Committee on Science and the Arts.

Dr. Joseph W. Richards, Lehigh University, gave a brief preliminary account of the Theory of Harmony announced by Professor Goldschmidt of the University of Heidelberg. (The subject will be presented *extenso* at the meeting of the Physical Section on Monday, January 22d.

Dr. Henry Leffmann made some remarks apropos to the proposal now before the National Congress to establish a Forest Reserve in the Southern Appalachian Mountains, and illustrated the subject with the aid of lantern views. It was voted to give the sanction of the Institute to the project by becoming a member of the Appalachian Park Association.

Mr. Edwin A. Heyl exhibited and described an improvement in horns for talking machines, which the inventor termed the "Vocalophone." The advantages claimed for the new horn were demonstrated by a comparison of reproductions of vocal and musical records with the horn commonly used and the improved device.

A memorial of the late Luther R. Paught, life-member of the Institute, prepared by Dr. Edwin J. Houston, was presented by the Secretary and referred to the Committee on Publications.

Adjourned.

WM. H. WAHL, *Secretary.*

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## ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE FOR THE YEAR 1901.

[WITH APPENDICES.]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 8, 1902.

*To the Members of the Franklin Institute.*

The record of 1901, like those of recent years, while satisfactory in a number of features, is not encouraging when the work which the Institute has done, and that which it could and should do, are contrasted. The increase of membership is welcomed as adding to the interest of the Institute, and as aiding somewhat its income. The attendance at meetings, the character of the papers presented, and the work of Sections are all gratifying evidences that the members feel a lively interest in the work of the organization, but there is unfortunately constantly before us the knowledge that local appreciation is wanting of what the Institute has accomplished and of the assistance it could render the public.

That we command the services of noted specialists who deliver lectures or present papers before the Institute or its Sections; that the *Journal* is widely circulated and gladly received in exchange for the most noted publications throughout the world; that membership in the Institute is recognized as an honor, and that the verdict of the Committee on Science and the Arts is sought by inventors, are gratfying evidences of appreciation; but the condition which faces the Institute is, that each year it is necessary to supplement the income from regular sources by voluntary contributions to maintain the work in at least an apparently satisfactory condition.

The Franklin Institute should not for one moment have to consider whether a book could be purchased, but should have the money ready to add any domestic or foreign publications to its library which come within the list of technical or mechanical works. Its Sections and Committees should be more liberally supported, thus providing for advanced usefulness and greater value to the Institute and to the public at large.

It is essential that something should be done to attract attention to the Institute and its functions, and to obtain from the public such assistance as will be serviceable, in fact necessary to carry on its work as it should be done, especially as the reduction of interest rates on investments makes the work of sustaining the Institute, as it should be conducted, more difficult each year. That it has work to perform in the future, as in the past, is admitted; to perform it creditably a large revenue is necessary; to obtain this revenue there are several possible methods.

(1) The roll of members can be augmented and the dues of members could be increased, a policy which many technical societies have been compelled to adopt.

(2) Appropriations from municipality, State or Government could be solicited, and although they have been earned by public service rendered be the Institute in the past, and undoubtedly would be repaid with interest in the future, the acceptance of such assistance might not be without drawbacks. The Institute to-day stands entirely untrammeled, and the reports of its work now go before the world free from the taint of partisan, factional or political significance.

(3) An increase in facilities could be secured by a sufficient endowment, the annual interest from which would yield a sufficient income for the needs of the Institute; or, annual contributions might be solicited for which some direct return could be made to various industries or organizations specially benefitted by the Institute's work.

The third plan seems to be the most helpful and desirable, and it is believed that if the members of the Institute could be brought to co-operate, each doing what he or she could, the result would be most satisfactory.

A sufficient endowment would also indirectly aid the effort to secure better accommodations in a more desirable location, a subject of the deepest interest to the Board of Managers, and which is now in the hands of a special committee. Greatly as we revere the old building, which, for more than three-quarters of a century has been the home of the Institute, the Board realizes that business changes have made the present location undesirable, and that the requirements of the organization demand better accommodations. But the limitations of our treasury and the charter under which the Institute exists prevent taking this most desirable step without financial aid.

The Institute, recognized as a useful organization for more than three-quarters of a century, with a world-wide reputation, commonly is credited with having ample funds. It is unfortunate that this is not the case, and equally unfortunate that the increasing demands of the present time, coupled to the decreasing interest rate, make the maintenance of the work more difficult than in past years.

A united effort on the part of the membership should bring the Institute into a position of financial ease and permit it to enlarge its field of usefulness both for the present and the future.

Reports of the various committees, hereto appended, will indicate that the year's work throughout has been well done, and attention is called to the several instances during the year where the Institute has taken up problems of general interest. At present there are under discussion, in the hands of

special committees, the Metric System of Weights and Measures and the Hazards to Life and Property associated with our rapid industrial progress.

The Institute is ready now, as in the past, to carry forward investigations which advance science and the arts, or which in any way benefit the general public. Its large membership of men skilled in science and practice has always responded to the call of the national, State and city government, and has rendered without compensation services which could not otherwise be secured unless at heavy expense. These public services should invite such generous appreciation as will place the Institute in position to carry on its unselfish work with greater effectiveness.

By order of the Board.

JOHN BIRKINBINE,
*President.*

FINANCIAL STATEMENT FOR THE YEAR 1901.

| | |
|---|---|
| Balance on hand January 1, 1901 | $1,051 86 |
| Receipts in 1901 | 32,206 23 |
| Payments in 1901 | 32,208 13 |
| Balance on hand January, 1902 | $1,049 96 |

## APPENDICES.

REPORT OF THE COMMITTEE ON ELECTION AND RESIGNATION OF MEMBERS, 1901.

| | | |
|---|---|---|
| Members at the close of 1901 | 2,287 | |
| New members elected in 1901, who have qualified | 153 | |
| | | 2,440 |
| Lost by death, resignation and non-payment of dues | | 97 |
| Total membership at the end of 1901 | | 2,343 |

ALEXANDER KRUMBHAAR,
*Chairman.*

## ANNUAL REPORT OF THE COMMITTEE ON INSTRUCTION, 1901.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 1, 1902.

*To the Board of Managers.*

The Committee on Instruction has continued the arrangement with the Central Branch of the Young Men's Christian Association for two courses of popular scientific lectures during the autumn and winter seasons. The services of the lecturers, as heretofore, have been obtained gratuitously, and the Committee recommends that a suitable acknowledgement be made to the gentlemen who have so generously co-operated in the educational work of the Institute.

The statistics of the schools exhibit a substantial increase in the number of pupils, especially, in the Schools of Naval Architecture and Machine

Design. The growth of interest in these comparatively new undertakings appears to have fully justified the Committee in proposing their establishment.

Following are the figures of attendance as compared with the preceding year:

| | 1900. | 1901. |
|---|---|---|
| Drawing School | 298 | 299 |
| School of Naval Architecture | 61 | 97 |
| School of Machine Design | 61 | 80 |
| Totals | 420 | 476 |

The Committee is fully satisfied with the zeal and ability of those in charge of the schools.

Respectfully,

WILLIAM H. WAHL,
*Chairman.*

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## ANNUAL REPORT OF THE COMMITTEE ON PUBLICATIONS FOR 1901.

*To the Board of Managers.*

The Committee on Publications deems it a subject for congratulation that the *Journal* of the Institute has, of late years, become in reality what its name would imply, viz., the medium for the recording and publishing of papers and communications representing the scientific activity of the various branches of the Institute.

For this highly satisfactory condition, the several sections—at present numbering six—deserve the credit; and the Committee feels satisfied, from the evidence afforded by the *Journal*, that at no time in its history has the Institute displayed so much and such varied scientific activity as at the present time.

The Committee has not felt the necessity for a number of years of seeking outside material to fill the pages of the *Journal*, and from present indications of the activity of the Sections there will be no need of this for the future, the amount of material in reserve for publication being at all times more than sufficient for the Committee's requirements.

The society publications and periodicals received in exchange for the *Journal* at the close of 1901 numbered 512, an increase of 15 over the previous year. The value of this mass of literature added annually to the library may be estimated conservatively at $1,600.

THEODORE D. RAND,
*Chairman.*

## ANNUAL REPORT OF THE COMMITTEE ON THE LIBRARY FOR THE YEAR 1901.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 6, 1902.

*To the President and Members of the Franklin Institute.*

GENTLEMEN:—The Committee on the Library respectfully reports the following summary of the operations of the Library during the year 1901:

ADDITIONS.

| | Bd. Vols. | Unbd. Vols. | Pphs. | Chts. | Phts. | Engrs. | Drawings. |
|---|---|---|---|---|---|---|---|
| By Gift | 530 | 320 | 844 | 26 | 11 | 6 | 1 |
| Exchange | 25 | 1 | 2 | | | | |
| Binding | 67 | | | | | | |
| From Com. on Pub. | 46 | 17 | 12 | | | | |
| Purchase | 74 | 50 | | 2 | | | |
| Lea Fund | | 3 | | | | | |
| | 740 | 391 | 858 | 28 | 11 | 6 | 1 |

Total additions for the year . . . . . 2,035

A decrease of 1,374 from 1900, and of 802 from 1899.

Total number of volumes, January 1, 1902 . . . . . 53,360

Total number of pamphlets, January, 1902 . . . . . 37,891

The Library also contains 2,855 maps and charts, 659 designs and drawings, 1,225 photographs, 191 newspaper clippings, 30 manuscripts.

BINDING.

| | |
|---|---|
| Periodicals reported among the additions | 67 |
| Old books | 29 |
| Lea Fund books | 1 |
| Rebound | 5 |
| | 102 |

*Exchanges.*—Five hundred and twelve societies and publications were on the exchange list of the *Journal* during the year 1901, an increase of 15 over 1900.

It is twenty years since the yearly additions to the Library have been so few. All sources of income the past year have temporarily been almost wholly cut off, few books were bought, little binding was done, and the additions were mainly made up of special gifts, even more than is usually the case. Owing to financial circumstances, the Moore Fund, ordinarily yielding about $750 a year; the Memorial Library Fund, about $50 a year; and the James T. Morris Fund, about $100, have the past year supplied no books; and the Lea Fund, about $150 a year, very few. The prospect is now good for the usual income from all the funds in the coming year.

Some years ago the Librarian found by actual count that the number of visitors to the Library, though variable, according to the weather and season, averaged about 150 daily, two-thirds of them in search of patents. The

number still continues apparently undiminished or increasing. The Library, with its more than 95,000 volumes, pamphlets, maps and drawings, and its large daily attendance, is unquestionably the most important feature of the Institute; and clearly every effort should be made to maintain and augment its usefulness.

It is extremely important that the binding be virtually brought up to date as regards the complete sets of current periodicals during the coming year, by binding about 500 volumes, at an expense of about $450. After that, about $300 a year would cover the cost of binding and make it possible to bind all the serial publications as soon as each volume is completed, so that the sets could be kept in better condition and be more useful for reference. In addition, a large number of not yet completed sets of periodicals could, with great advantage, be bound up at once if there were any funds for the purpose. The cost would probably be $250

The Board of Managers has lately granted to the Library the use of the northern room near the front door on the lower floor, and a large portion of the required shelving has just been put in at the cost of nearly $100, yet to be paid. The rest of the shelving can be put in later and will cost about $50. At that time it will be necessary to put in electric lighting also, at a cost of perhaps $25. A small gallery should also be built for the upper shelves, and a little staircase to reach the gallery. The room is perfectly fireproof, excepting the very slight risk from the window and door. Perhaps means may later be found to replace the window with wire-glass and to add an inexpensive fireproof door outside the present one. The additional book-room came not a day too soon; for books already had to be removed to the floor from the shelves of the main book-stack to make space for important acquisitions of patent publications in frequent use. The new room will be used for books that are less frequently consulted and for the nearly 38,000 pamphlets.

This rapidly growing and immensely valuable collection of pamphlets has for many years necessarily been lying in disorder and unusable in the part of the third-story that is not fireproof. They can now be gradually removed to the new room, and at least roughly arranged, as soon as pamphlet cases and a little additional assistance can be provided. About 15,000 of them have already been catalogued. There is very pressing need that they should all be catalogued and thoroughly arranged; but for that purpose it would be necessary to employ permanently at least one more assistant in the library, at an expense of about $10 a week.

That assistant would also make possible more complete attention to a very important part of the library work that has for some years had to be neglected from want of sufficient force; and that is, the constant watchful pursuit of numerous municipal and governmental serial publications of great engineering value, and countless trade catalogues, highly useful when methodically arranged. They are willingly sent without cost to the library, since it is an unexcelled repository for such works. Yet, with the frequent change of officials and clerks, the Library is but too apt by oversight to be dropped from mailing lists, unless the Library keeps a careful lookout and sends a timely reminder when an expected publication is missing.

The Library has a collection of 500 maps of the U. S. Geological Survey. The sheets are valuable, and some are out of print. They are frequently

used, and for want of proper room are getting badly torn and seriously damaged. A suitable case should be provided with space for a thousand sheets. If the charts were arranged according to States in shallow drawers, with room enough, it would not be necessary to handle all the maps when only one is needed.

The cost, then, of satisfying the more pressing needs of the Library, beyond the ordinary expense for the coming year, would be:

| | |
|---|---|
| Binding, mainly completed sets of periodicals | $450 |
| Binding periodicals of sets not yet completed | 250 |
| Fitting up the new book-room, about | 250 |
| An additional assistant, about | 500 |
| Map case, perhaps | 100 |
| | $1,550 |
| In addition, certain very much needed books not within the power of the special funds would cost about | 1,000 |
| | $2,550 |

The members of the Library Committee still continue to show great zeal in their work, and co-operate harmoniously for the interest of the Institute.

BENJAMIN SMITH LYMAN,
*Chairman.*

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## ANNUAL REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS FOR THE YEAR 1901.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 1, 1902.

*To the President and Members of the Franklin Institute.*

The following report of the Committee on Science and the Arts is respectfully submitted:

| | | |
|---|---|---|
| The number of cases pending on December 31, 1901 | 48 | |
| The number of new cases proposed by application was | 36 | |
| By reference from Institute | 3 | |
| By reference from Sections | 1 | |
| By vote of the Committee | 5 | |
| Total number of new cases in 1901 | 45 | |
| Total number of cases before Committee in 1901 | | 93 |
| Number of cases acted upon | 51 | |
| (of which there are pending 5.) | | |
| Finally determined | 46 | |
| Cases pending December 31, 1901 | 47 | |
| | | 93 |

The forty-six cases completed were determined as follows:

| | |
|---|---|
| Award of Elliott Cresson Medal | 4 |
| Award of John Scott Medal | 12 |
| Award of Edward Longstreth Medal | 4 |
| Award of Certificate of Merit | 1 |
| Reports without Award | 5 |
| Reports advisory | 2 |
| Cases withdrawn | 1 |
| Cases dismissed | 17 |
| Total | 46 |

The Committee has been more or less hampered throughout the year by the difficulty in obtaining a sufficient quorum of its members to take final action on the reports at hand, and still more by the insufficiency of its membership to deal expeditiously with the numerous cases before it. The investigation of the subjects proposed for consideration frequently demands of the Sub-Committees the devotion of much time and effort to the proper elucidation of their respective subjects, and as these investigations must necessarily be made by experts and professional men whose time is largely preoccupied, and whose service in this work is given gratuitously, it follows, of course, that the work proceeds less rapidly than is desirable. The summer months being, furthermore, virtually eliminated from the working time of the Committee, its activity is thus practically limited to some nine months of the year.

In view of these conditions it is recommended and proposed that the membership of the Committee be increased from its present number of forty-five (45) to sixty (60). The additional force doubtless would serve to add materially to the Committee's efficiency and to relieve its individual members of too onerous a burden.

Pursuant to the resolutions of the Institute the Committee has proceeded to the preparation of properly engraved diplomas of award to accompany the several medals now within the gift of the Institute. The details of this matter, as embodied in the report of the Sub-Committee having the work in charge, form the subject of a communication from the Committee to the President and Board of Managers of the Institute, under date of the 4th ult., and the proposed action having on the 11th ult. received the approval of the Board, the engraving and printing of the three diplomas in question, namely, the Elliott Cresson, the Edward Longstreth and the John Scott Medals have been ordered to execution by the American Bank Note Company in accordance with proposition and design submitted by that company under date of November 26th ult., and the work will be completed in due course.

LOUIS E. LEVY, *Chairman.*

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## ANNUAL REPORT OF THE COMMITTEE ON MEETINGS, 1901.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 1, 1902.

*To the President and Members of the Franklin Institute.*

The Committee, with the Secretary's aid, arranged the program of the ten stated monthly meetings of the past year, as required by the by-laws.

These arrangements involved the presentation of eighteen communications, and of a number of subjects that were presented informally.

The average attendance at the meetings during the year exhibits a substantiated increase as compared with the several years immediately preceding. A number of the topics presented afforded acceptable material for the *Journal.*

The publication of the Monthly Bulletin has been continued as heretofore, and notwithstanding its considerable cost, the Committee believes it would be very unwise to discontinue it.

Several important subjects presented at the meetings have given cause for the appointment of special committees for their consideration, and it is anticipated that the investigations of these committees will prove of substantial value.

WASHINGTON JONES, *Chairman.*

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## ANNUAL REPORT OF THE CHEMICAL SECTION FOR THE YEAR 1901.

*To the Committee on Sectional Arrangements.*

During the year 1901 the Chemical Section held seven stated meetings, at which the following subjects were presented and discussed:

Dr. W. J. Williams. "What Constitutes an Explosive?"

Mr. Lyman F. Kebler. "What does the Designation C.P. Mean?" "A New Method for Chromic Acid and the Soluable Chromates;" "A Communication on Walnut Oil."

Prof. F. W. Clarke. "The Chemical Work of the U. S. Geological Survey."

Mr. W. E. Ridenour. "The Chemistry of Deposits in Steam Boilers;" "The Estimation of Caustic in the Presence of Alkali Carbonate."

Dr. Jos. W. Richards. "Some Abridgements of Chemical Calculations."

Dr. Robert H. Bradbury. "Some of the Researches of Professor Spring, of Liége;" "The Goldschmidt Process for the Reduction of Certain Metals and the Production of High Temperatures."

Dr. H. F. Keller. "Moissan's Work on Fluorine and the Fluorine Compounds;" "The Shimer Crucible for Carbon Combustions."

In addition to the above, several of the meetings were devoted to the exhibition of numerous new and interesting chemical lecture experiments (Drs. Keller, Bradbury, Leffmann and Sadtler). Mr. Wm. McDevitt presented some instructive experiments suggested by explosions at fires; and Dr. Keller showed and commented on a fine series of lantern-slides illustrative of historical chemistry.

The membership of the Section has been fully maintained, and the general interest of the members continues unabated.

The program for the first semester of 1902 is of unusual interest.

HARRY F. KELLER,
*Chairman of Executive Committee.*

## ANNUAL REPORT OF THE ELECTRICAL SECTION FOR THE YEAR 1901.

*To the Committee on Sectional Arrangements.*

The Electrical Section held eight meetings during the year 1901, a number of which were fruitful of valuable papers.

The interest of the membership in the work of the Section and the general activity of the Section's affairs are noted with satisfaction. A number of the papers presented during the year have appeared in the *Journal*.

Following is a list of communications presented:

Mr. Carl Hering. "Three-Phase Electric Traction in Europe."

Dr. Joseph W. Richards. "Secondary Reaction in Electrolysis."

Mr. Charles Wirt. "Theatre Dimmers and Stage Lighting."

Mr. W. J. Hammer. "Recent European Electrical Progress."

Mr. Edwin S. Church. "Minting Machinery and Appliances."

Dr. A. E. Kennelly. "The Edison Storage Battery."

Mr. C. J. Reed. "Polarization in Batteries."

Mr. Paul M. Lincoln. "The Parallel Operation of Alternating Current Generators."

Mr. A. J. Wurts. "Development of the Nernst Lamp in America."

Subjects for discussion were communications by Messrs. Hering, Kennelly, Eglin and others on "The Electrical Arts at the Pan-American Exposition," and a paper by Mr. C. J. Reed on "Electro-Chemical Action."

The prospects of the Section for the immediate future are most satisfactory.

WILBUR M. STINE,
*Chairman Executive Committee.*

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## ANNUAL REPORT OF THE MINING AND METALLURGICAL SECTION FOR THE YEAR 1901.

*To the Committee on Sectional Arrangements.*

The proceedings of the Section have been duly conducted by the following officials:

*President*, F. Lynwood Garrison.

*Vice-Presidents*, Arthur Falkenau and Spencer Fullerton.

*Secretary*, G. H. Clamer.

*Conservator*, Dr. Wm. H. Wahl.

*Membership.*—The total membership shows increase of two over 1900.

*Meetings.*—The Section held nine meetings during the year.

*Work of Section.*—The papers presented were of unusual interest, as was also a discussion on the subject of "Moulding Machines and Foundry Practice," and a discussion pertaining to products of mining and metallurgical interest, as exhibited at the Pan-American Exposition, to each of which an evening was devoted. All communications were considered of sufficient importance to be published in the *Journal*.

Following is the list of papers presented:

Dr. John A. Mathews, } "The Constitution of Metals and Binary Alloys."
Mr. Wm. Campbell, }

Mr. Richard L. Humphrey. "The Inspection and Testing of Cements."

Prof. F. L. Garrison. "Effects of Deforestation in Northern China."

Mr. Joseph Richards. "Utilization of Waste from the Use of the White Metals."

Caspar Wistar Haines. "Remarks on the Earthquake, January 16, 1900, in the State of Colima, Mexico."

G. H. CLAMER, *Secretary.*

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## ANNUAL REPORT OF THE MECHANICAL AND ENGINEERING SECTION FOR 1901.

*To the Committee on Sectional Arrangements.*

The Section has a membership of 199. It has held eight meetings, four of which have been devoted to the general discussion of topics of importance. The average attendance at the meetings has been 33, which should be greater for a section as large as this. To increase the interest at the meetings it has been proposed to have monthly reviews of progress in various branches in engineering.

A list of the subjects presented and discussed during the year is hereto appended.

DANIEL EPPELSHIMER, JR.,
*Secretary.*

*January.*—"The Wear and Tear of Steam Boilers" (being the address of the retiring President), Mr. John F. Rowland, Jr.

*February.*—"The Jig Habit in America." Mr. Oberlin Smith, Bridgeton, N. J. Illustrated with specimens and models.

*March.*—"The Automatic Gun and Its Military Aspects." Cecil H. Taylor, Bound Brook, N. J.

*April.*—"Invention and the Rights of Inventors." S. Lloyd Wiegand.

*May.*—"Moulding Machines and Modern Foundry Practice." Discussion. (Opened by Wilfred Lewis.) The subject was illustrated by the exhibition of the machine operated by compressed air.

*October-November.*—"Steam Boiler Design and Inspection, with Special Reference to the *City of Trenton* Disaster." Discussion by Messrs. Samuel M. Vauclain, John M. Hartman, George B. Hartley, Washington Jones, R. D. Kinney and James Christie. The subject was illustrated by specimen test pieces and bolts from the exploded boiler shell, and lantern slides.

*December.*—"The Renold Silent Chain-Gear." Mr. J. O. Nixon, Link-Belt Engineering Company, Philadelphia. Illustrated by specimen gears, and numerous lantern slides showing the application of the gear to a variety of machines.

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## REPORT OF THE SECTION OF PHOTOGRAPHY AND MICROSCOPY FOR THE YEAR 1901.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 1, 1892.

*To the Committee on Sectional Arrangements.*

The meetings of the Sections have been well attended during the entire year, and the communications presented have been of considerable interest and novelty. The principal part of the work refers to photography, and it is

hoped that an effort may be made to discuss questions relating to microscopy more fully in future.

The following is a summary of the matters presented during the past year:

*January 3d.*—Address of Retiring President. Subject: "Application of Photography to Police and Sanitary Administration."

*February 7th.*—"Effect of Time on the Sensitiveness of Photographic Materials." Dr. C. F. Himes.

"Effect of Light on Chemicals, Especially Mercurous Compounds." Henry Leffmann.

"The Wager Exposure Scale." E. Wager-Smith.

*March 7th.*—"Use of Lantern-Slides for Class Demonstration." Dr. I. N. Broomell.

"An Exposure Meter." John G. Baker.

"Suggestions for Labeling Lantern-Slides." Henry Leffmann.

*April 4th.*—"Exhibition of views of a newly discovered cave at Mapleton, Pa." W. N. Jennings.

*May 2d.*—"Photographic record work." General discussion.

"A New Lantern Polariscope." F. E. Ives.

"Lothian Stereoscope." Dr. C. F. Himes.

*October 3d.*—"Application of Photography to Legal Records." Dr. Henry Leffmann.

*November 7th.*—"Use of Sensitive Paper in X-Ray Work." M. I. Wilbert.

*December 5th.*—"Experiments on Over-Exposure and Reversal in Photography," with demonstrations by U. C. Wanner and M. I. Wilbert.

The Section gave some time to the consideration of a plan for holding a general photographic exhibition, but the question has been laid aside for the present.

Respectfully submitted,

HENRY LEFFMANN,
*Chairman of Executive Committee.*

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## REPORT OF THE PHYSICAL SECTION OF THE FRANKLIN INSTITUTE. FEBRUARY, 1901—DECEMBER, 1901.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 1, 1902.

*To the Committee on Sectional Arrangements:*

To those in Philadelphia and its vicinity who are interested in Physics, Astronomy and Geophysics, it should be a cause of satisfaction that during the past year the Physical Section of the Franklin Institute has maintained so vigorous an existence. Nine meetings have been held in the eleven months with an average attendance of about twenty. Eighteen papers have been presented, of which a list is appended. More than this, it has not been difficult to secure the communications above mentioned. It would seem that the Physical Section supplies an opportunity hitherto lacking for the presentation of new work before a sympathetic and appreciative body.

It has proved to be an easier matter to obtain the communications than to secure an audience fitting to their interest and high character. It is, however, to be remembered that the sciences to which the Section is dedicated

appeal to a very limited number of persons. Physics and Astronomy connotate the laboratory and observatory and these, save in rare instances, are found in connection with institutions of education only. In this is found an explanation of the fact that both for papers and for regular attendants the Section has had to rely chiefly, though by no means entirely, upon teachers in either colleges or high schools. Of the eighteen papers no less than sixteen were presented by men connected with such institutions. It is to be hoped that some way may be devised of making the work of the Section appeal to a wider audience. In addition to the regular monthly meetings the Section may properly claim the credit for the appearance of Dr. Stratton before the Institute.

We may further congratulate ourselves that the Section has in no case left the arrangement of the meetings and the obtaining of papers to the Secretary of the Institute. This evidence of an independent life augurs well for the future.

GEORGE F. STRADLING,
*President.*

## APPENDIX.

List of papers presented before the Physical Section of the Franklin Institute. February, 1901–January, 1902.

1901.

*February*—"On Certain Harmonic Curves." Dr. H. C. Richards.

"The Geometric Chuck and Curves Produced by It." Dr. E. A. Partridge.

*March*—"Antarctica: A History of Antarctic Discovery." Mr. E. S. Balch.

"Thermometer Glass at Higher Temperatures." Mr. Wm. McClellan.

*April*—"E. H. Lenz as one of the Founders of the Science of Electro-Magnetism." Prof. Wilbur M. Stine.

"Recent Progress in Double-Star Astronomy." Prof. E. Doolittle.

*May*—"A New System of Making Corrections in Calorimetric Experiments." Dr. Joseph W. Richards.

"Historical Sketch of the Measurement of the Dimensions of the Earth." Mr. H. I. Woods.

"Preliminary Note on Crystallization under Electrostatic Stress." Dr. Paul R. Heyl.

*September*—"Crystallization under Electrostatic Stress" (Second Communication). Dr. Paul R. Heyl.

Reviews of Recent Progress.

"Light." Dr. H. C. Richards.

"Electricity." Dr. M. G. Lloyd.

*October*—"Heat." Mr. William McClellan.

*November*—"The Question of the Divisibility of the Atom." Dr. A. S. Mackenzie.

"Report on Period of Rod Vibrating in a Liquid."

"Report on Absoption Spectrum of Chlorine." Both reports given by Dr. Mackenzie.

"Recent Progress in Sound." Dr. Geo. F. Stradling.

*December*—"Mechanism and Causation of Hot Waves." Mr. Harvey M. Watts.

# SECTIONS.

(*Abstracts of Proceedings.*)

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—Proceedings of the thirteenth *Stated Meeting*, held Thursday, December 5, 1901. Dr. Henry Leffmann in the chair. Present, 31 members.

On motion, it was resolved to ask the Board of Managers for an appropriation of $75 for the expenses of the Section for the year 1902.

The Executive Committee was directed to report at the next stated meeting nominations for officers of the Section to serve for the year 1902.

Mr. Wanner presented a communication on the making of "Reversed Pictures and their Development in Actinic Light." The speaker showed some samples of reversed pictures, and also demonstrated the development of these pictures before the meeting.

Dr. Leffmann called attention to a communication of Professor Nipher, lately read before the St. Louis Academy of Science, a copy of which was laid on the table for inspection by members.

Mr. Wilbert showed some samples of normal and reversed negatives, and called attention to the wide range of exposure that was possible, using the same plate and normal developer.

Mr. Samuel Sartain invited attention to several pictures that he had made accidentally. These were developed in the dark room.

The subject was further discussed by Messrs. Leffmann and Ridpath.

Mr. F. E. Ives followed with a description of a novel stereogram, for which he proposed the name of the Parallax Stereogram, and described the method of taking the pictures. (See the *Journal*, January, 1902).

Dr. Leffmann called attention to the programs arranged for the succeeding meetings. Adjourned.

M. I. WILBERT,
*Secretary pro tem.*

Proceedings of the fourteenth *Stated Meeting*, Thursday, January 2, 1902. Dr. Charles F. Himes in the chair. Present, 22 members and visitors.

The retiring President presented his annual address, the subject being "Photographic Permanence and the Work of the Amateur Photographic Exchange Club of 1860–64." The paper was fully illustrated with a number of prints made upwards of forty years ago.

The annual report of the Section, prepared by the Executive Committee, was read and approved. The same Committee reported a list of nominations of officers of the Section for the year 1902, which was approved, and the Secretary was instructed to cast the ballot of the meeting for the nominees.

The following gentlemen were thereupon declared elected to the offices set opposite their names:

*President*—Dr. Henry Leffmann.
*Vice-Presidents*—F. E. Ives, J. W. Ridpath.
*Secretary*—Martin I. Wilbert.
*Conservator*—Dr. Wahl.

The meeting ordered the incorporation in the Section's records of the following tribute to the memory of the late John G. Baker, Vice-President of the Section, viz.:

"The members of the Section of Photography and Microscopy desire to record their sorrow for the death of their fellow-member and Vice-President, John G. Baker. Our memory of him is not only of his geniality and sincerity, but also of his integrity and his zealous work in the interest of the Section from the first hour of its existence.

"Our published records contain numerous contributions from him, supplementary to, and descriptive of, valuable and novel plans in photography. By his death we have lost an active and companionable associate, and photographic art and science has lost an industrious votary. Adjourned.

MARTIN I. WILBERT, *Secretary.*

MINING AND METALLURGICAL SECTION.—Proceedings of the *Stated Meeting* held Wednesday, January 8, 1902, Prof. F. Lynwood Garrison, President, in the chair. No quorum being present, the papers of the evening, viz., the Annual Address of the retiring President and the "Pocono Coal of Berkley and Morgan Counties, W. Va.," by Mr. William Griffith, Mining Engineer, Scranton, Pa., were read by title.

WM. H. WAHL,
*Secretary pro tem.*

MECHANICAL AND ENGINEERING SECTION.—Proceedings of the *Stated Meeting* held Thursday, January 9, 1902. Mr. A. M. Greene, Jr., in the chair. Present, 42 members and visitors.

The annual election resulted in the election of the following:

*President*—A. M. Greene, Jr.

*Vice-Presidents*—Arthur Falkenau, Charles Day.

*Secretary*—Daniel Eppelsheimer, Jr.

*Conservator*—Dr. Wahl.

The principal communication of the evening was read by Prof. Emory R. Johnson, University of Pennsylvania, on "The Engineering and Commercial Features of the Isthmian Canal." The speaker discussed the work of the Isthmian Canal Commission, and gave a summary of the results embodied in its report, and commented on the relative merits from the engineering and commercial standpoint of the several projects for the passage of the Isthmus. (The paper will appear in the *Journal*).

Mr. Francis Head followed with a paper on "The Use of Fuel Economizers in Connection with Steam Plants," which was fully illustrated with the aid of lantern slides.

DANIEL EPPELSHEIMER, JR.,
*Secretary.*

ELECTRICAL SECTION.—*Stated Meeting* held Wednesday, January 16th, 8 P. M. President Morris E. Leeds in the chair.

A communication on "The Mechanical Efficiency of Illumination" was presented by Mr. Thomas Spencer.

Dr. E. F. Roeber opened the discussion of the subject of "Some General Principles Concerning the Design of Galvanic Cells." Messrs. Henry, Reed, and Stine participated in the discussion.

The election of officers to serve the Section for the year 1902 was postponed until the stated meeting of February.

RICHARD L. BINDER, *Secretary.*